CENTRAL CONNECTICUT
RAIL STUDY

DIESEL MULTIPLE UNIT ALTERNATIVE

CONNECTICUT DEPARTMENT OF TRANSPORTATION
STATE PROJECT NUMBER: 171-366

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Executive Summary

This report provides an overview of Diesel Multiple Unit (DMU) rail vehicles and their potential for operation within the Connecticut Department of Transportation's (CTDOT's) commuter rail system. This report is not intended to provide a recommendation, but provide decision makers with information regarding the application of DMU equipment. The report includes a review of DMU technology and equipment, case studies of other commuter rail and transit agencies that operate DMUs and lessons learned from these systems. An analysis of the feasibility for service along Connecticut's commuter rail branch lines is presented to determine whether CTDOT would benefit from implementing DMU service along its lower density lines as well as potential new passenger routes through rural areas.

Diesel Multiple Units (DMU) are multiple unit trains powered by on-board diesel engines that do not require separate locomotives or an overhead catenary system to operate. They have been considered by a number of US transportation agencies as an alternative for conventional push-pull train sets on non-electrified rail. Some industry experts have argued that DMUs can be operated with fewer cars, and with greater flexibility and efficiency for rail lines with lower ridership. Connecticut DOT has requested an analysis be performed to determine whether DMUs on existing or future branch lines provide a cost effective alternative to the Department's existing commuter rail equipment and whether or not they are a viable option for Branch line service.

Brief History of DMUs

DMUs once operated on many passenger rail lines in the U.S., including Connecticut's Hartford Line, Danbury and Waterbury Branch, as well as the former Waterbury Secondary passenger line and former rail lines connecting to Boston. The vehicles, built by the Budd Company, were known then as Rail Diesel Cars (RDC). RDCs were the rail industry's response to dwindling ridership in the 1940's and 50's. It was a Budd RDC that is known to be the last passenger rail equipment operating on the Waterbury Secondary. They continued operations on other lines in Connecticut until the 1970s. This equipment fell out of favor in the resurgence of commuter rail beginning in the 1980s, due to its lower reliability, although there are still some RDCs in operation in the US.

DMUs resurfaced as an alternative to conventional rail equipment in the early 1990s in the US with the US built Colorado Railcar. European DMU equipment was also introduced and tested by Amtrak and other agencies, including the Siemens Regio Sprinter and the Adtranz IC-3 Flexliner. Only the Colorado Railcar, however, met U.S. Federal Railroad Administrations compliance standard for crash worthiness, which would allow it to operate in shared track with freight and other heavy rail equipment. The non-compliant DMU equipment can operate only with temporal separation on freight lines (operating when freight is not in operation) unless a waiver is received from FRA. Today, several U.S. transportation systems operate FRA compliant as well as non-compliant equipment following FRA rules. For this review, only FRA compliant equipment was considered for operations in Connecticut, as the

Department prefers not to seek FRA waivers and needs the flexibility to operate in mixed freight-passenger rail traffic without the restrictions of temporal separation, as well as with an ability to operate short distances on main line track such as the New Haven line.

Case Studies of current/planned DMU service in the US

More than 10 DMU systems either already in service or planned were reviewed for their relevance to potential DMU operations in Connecticut. This included both compliant and non-compliant systems to determine whether there are significant cost differences. Table A, shown at the end of the Executive Summary, presents key data for 12 systems (nine that are in service, three in planning stage).

Operations on Waterbury Branch and future Waterbury Secondary

DMUs were reviewed for their potential use on the Waterbury Branch as well as possible future operation on the Waterbury Secondary or other light density lines in Connecticut. In addition, potential use of DMUs on the new Hartford Line was considered. Based on the research conducted, the following are key considerations for the deployment of DMUs in Connecticut :

Operating Issues

One of the key operating issues of DMU equipment in shared trackage with freight and other heavy rail equipment involves problems with track circuit “shunting” for detection of the DMU rail vehicle at highway grade crossings, and on rail corridors equipped with signal & train control systems. Due to their relatively light weight, DMUs have a history of inconsistent track circuit activation which has caused signal system problems wherein the DMU “disappears” momentarily from being detected by the grade crossing warning or signal system. Improved / higher sensitivity track circuit technology has been developed to minimize this problem as compared to the past. Continued review of this issue, however, is recommended.

Operating Costs

DMU operating costs are higher primarily due to the higher level of maintenance required. Information based on what is reported in NTD indicates most DMU service is at or above the industry average for conventional commuter rail.

Table B - Operating Costs for FRA Compliant DMUs

State	Provider	Cost per hour	Cost per mile
TX	Denton County Transportation Authority	$508	$18.93
TX	Dallas Area Rapid Transit	$587	$25.37
OR	TriMet	$942	$43.41
FL	South Florida Regional Transportation Authority	$566	$18.34

Table C - Average Operating Cost by Mode

	Average $/ rev hour
DMU compliant	$580
DMU non-compliant	$725
Commuter Rail	$523
Light Rail	$257
BRT	$154

Maintenance

A key concern of agencies trying to integrate DMU service with conventional rail equipment is how to combine maintenance service, as DMU equipment differs from standard heavy rail locomotives and cars. One concern is that DMUs require separate maintenance facilities due to the fact they typically operate with Cummins diesel engines more similar to bus engines than heavy diesel locomotives. However, the latest FRA compliant DMUs placed in service at GO Transit are maintained in the same facility as other heavy rail equipment. What is required, however, is separate inspection and maintenance training for those working on this equipment. CTDOT may be concerned that additional maintenance personnel would need to be hired, and uncertainty if the existing and planned railroad equipment facilities have the capacity to accommodate an operating fleet expansion beyond what already exists. Some CTDOT rail car maintenance equipment, such as wheel-truing lathes, and car wash facilities, may be able to be shared with a new DMU fleet.

Spare parts

In the event a foreign manufacturer is selected, obtaining DMU major equipment spare parts typically requires longer lead times of 8-10 months as compared to a US manufacturer. This could be a problem if a DMU fleet is very small and spare parts are not immediately available. Similar to a new bus fleet, a maintenance and repair parts inventory would need to be initiated to maximize DMU fleet availability.

Locomotive inspections

Since each DMU vehicle is self-propelled with an internal diesel engine, it must be inspected in the same frequency and certification levels as a traditional diesel locomotive. This can require more time and cost than conventional unpowered or electric rail cars; however other DMU fleet maintenance requirements can be utilized to formulate maintenance planning in CT.

Infrastructure Requirements

The experience of the majority of new DMU systems begun in the last decade in the US demonstrates that at a minimum the same level of infrastructure investment (track, structures, right of way) is required as with conventional rail equipment. A key reason is that the requirements most manufacturers of DMUs specify to effectively operate their equipment include requiring the track be maintained at a minimum of Class 4 (much higher operating speeds than what currently exists on the Waterbury Secondary freight line). Track tolerances for DMUs (vertical up and down variation as well as track gauge variation) are much tighter than on conventional railroad equipment. This equates to track and structures costs equal to or greater than what is needed for conventional rail. Cost savings can be realized, however, with shorter platforms and smaller stations if DMUs are deemed the primary passenger vehicles operating on the line.

	Service Name and Initiation Date	DMU Route, Track, speeds	# Stations, Ridership	Number, type of cars	Freight Use	Compliance, Other Notes	Capital Cost (per mile)	Operating Cost (per hour)
In Operation								
New Jersey Transit (NJT), NJ	River LINE (March 2004)	• 34.4 miles, Camden to Trenton, NJ, single and double tracked, 55 mph	• 21 stations, • 9,000 weekday riders	• 20 Stadler GTW	• Temporal by Conrail 10 PM to 6 AM	• Not FRA compliant, • Temporal separation waiver, • Operated by Southern New Jersey Rail Group	• $29.4 Million	• $674
North County Transit District (NCTD), San Diego County, CA	Sprinter (January 2008)	• 22 miles, Oceanside to Escondido, CA, with 8 miles of passing sidings • Top speed – 50 MPH	• 15 stations • 2.4M annual ridership	• 12 vehicles, Siemens (136 seated, 90 standing) • Level boarding, wide doors • Initial fleet 12 vehicles at $52.2 M (2008) ($4.4/car) • Operating costs - $11M/year;	• BNSF operates freight 3 nights/week. • Platforms are raised so freights can run.	• Not FRA compliant, regulated by California Public Utility Commission; NCTD received variance for some deviations from state regulations, but was required to improve braking • Operator: Veolia/Bombardier for maintenance	• $21.7 Million	• $609
Denton County Transportation Authority, Denton County, TX.	A Train (June 2011) Denton-Carrolton, TX	• 21 miles • Top speed – 50 MPH	• 6 stations • 2,000 daily ridership	• 11 Stadler GTW Cars and 10 BUDD cars	• Dallas Garland and Northeastern Railroad	• Non FRA-compliant vehicles but FRA Waiver granted to operate • Operator: Herzog	• $12.7 Million	• $508
Trinity Railway Express (TRE) Dallas/Fort Worth, TX	TRE	• 34 mile Commuter rail between Forth Worth and Dallas, TX	• 10 stations, 7,300 daily ridership	• 13 BUDD cars	• No fright but a mix of diesel locomotives with passenger cars and DMU used.	• FRA-compliant. DMUs used as spare vehicles • Operator: Herzog	• $7.6 Million	• $587
Capital Metro (CapMetro), Austin, TX	Red line (March 2010)	• 32 miles Austin to Leander TX	• 9 stations, • 1,500 passengers per day	• 6 Stadler GTW • 108 passengers seated	• Watco operates 2-3 freight trains a night	• Not FRA compliant, FRA Waiver for temporal separation, • Operator: Herzog	• $3.3 Million	• $1,186
TriMet, Portland, OR	Westside Express Service (WES) Line, February 2009	• 14.7 miles, Beaverton to Wilsonville, OR • Average speed 37 MPH; top speed 60 MPH •	• 5 stations, P&R at 4 stations • 512,000 annual ridership	• 4 Colorado Railcar/US Railcar and 2 BUDD • 95 passenger capacity. • Level boarding	• Shares track with Portland & Western	• FRA Compliant, • Commuter rail service	• $2.4 Million	• $942
Alaska Railroad	Chugach Forest Whistle Stop Service (May 2009)	• 60 MPH	• 5 Stations (only 2 are constructed)	• Colorado Rail Car	• Shares track with other Alaska Railroad locomotives	• FRA compliant	• $0.8 Million	• N/A
South Florida Regional Transportation Authority (RTA)	Tri-Rail commuter line (2006)	• 70.9 miles	• 18 stations • 14,800 daily ridership	• 4 Colorado Rail Car power units, 4 trailers, $5.01 M	• Shares track with CSX	• DMUs originally purchased for SunRail, used on Tri-Rail until SunRail opens	• N/A	• $566
GO Transit, Toronto, Ontario	Union Pearson Express	• 14.5 miles but only 1.86 miles of new track	• 4 stations • 2500 daily ridership	• 18 Nippon Sharyo units, compliant with U.S EPA Tier 4 emissions standards	• N/A	• Meets FRA Tier 1 Compliance standards	•	•

Chapter 1. Introduction and Purpose

1.1 Introduction

The purpose of this report is to present a possible alternative rail passenger vehicle technology, Diesel Multiple Units, commonly referred to as DMUs, and determine their applicability to commuter rail service along the Central Connecticut Rail Study (CCRS) corridor, as well as other rail corridors in the state. This report provides an overview of the DMU, its technology and equipment, case studies of other transit agencies that operate DMUs, and an analysis of its potential for service along Connecticut's commuter rail branch lines.

1.1.1 Project background:
The State of Connecticut, through the Connecticut Department of Transportation (CTDOT), has identified a need to conduct a study to determine the need and feasibility of enhanced passenger rail or transit service between Waterbury and Berlin. The Study Team has reviewed previous studies that have identified and addressed transportation needs within the CCRS Study Corridor. A summary of relevant study documents, highlighting their relationship to the CCRS, is included in this report.

1.1.2 Study Background

Project Purpose and Need
The purpose of the CCRS is to identify opportunities and develop a recommended plan to improve public transportation options for the traveling public in the Central Connecticut Rail Corridor between Waterbury and Berlin, CT.

The CCRS addresses several transportation-related concerns in the Study Corridor, identified through technical analysis, public input and agency involvement. The CCRS examines ways to address the following:

- The need to improve intercity transit mobility between Waterbury, Bristol, New Britain, and Hartford and to enhance intermodal connections within, to, and from the Study Corridor;
- The need to reduce roadway congestion in the Study Corridor;
- The need to maintain and improve existing freight service in the Study Corridor in a manner compatible with passenger rail service;
- The need to encourage transit-oriented development (TOD) opportunities within the Study Corridor and, where possible, to identify locations that may offer the most promising potential; and
- The need to identify optimal station locations and the attendant parking needs for rail service alternatives.

Alternatives Considered:
No Build – no new transit improvements. Only currently planned and programmed transit initiatives (with committed funds) would be constructed (CTfastrak and NNHS).

Transportation System Management – Implementation of upgrades to existing transit services that optimize facilities and operations without major capital investment.

BRT – Extend CTfastrak from New Britain through Plainville and Bristol to Waterbury using either a newly constructed dedicated busway that would be located adjacent to the existing rail tracks used for freight rail service, or converting an existing lane on I-84 and Route 72 to a dedicated busway lane.

LRT – Provide time-separated passenger service along the existing freight rail right-of-way on reconstructed track, using either Diesel or Electric vehicles.

Heavy Rail – Provide bi-directional passenger rail service along rebuilt track, high platform stations using either locomotives with coaches or DMUs. Requires bridge replacement/rehabilitation and possible double tracking.

Commuter Rail – Provide 30 minute peak and 60 minute off-peak bi-directional service with connections to MN Waterbury, CTfastrak and NHHS.

Intercity Service – Provide bi-directional service between Hartford and Bridgeport with a minimum of 4 trips per day.

1.2 Diesel Multiple Units (DMUs)

Diesel Multiple Units (DMU) are multiple unit trains powered by on-board diesel engines that do not require separate locomotives or overhead catenary to operate. This system helps reduce the infrastructure required and capital cost. The train units can come in various configurations such as married pairs, individual vehicles, and extra trailer cars that can be pulled or pushed. The sister system, Electrical Multiple Units (EMU), are the electrified version of DMUs. They are currently in service on the New Haven Line and are referred to as M-8s.

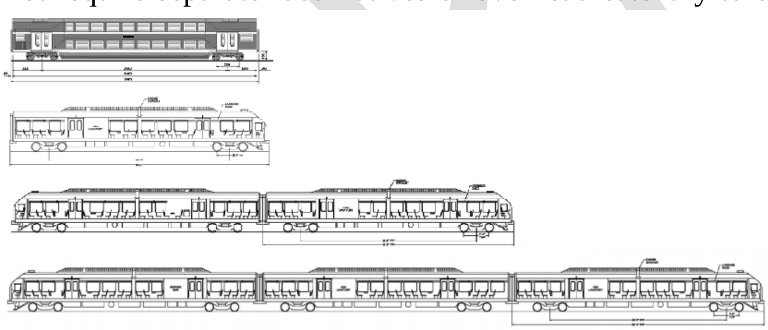
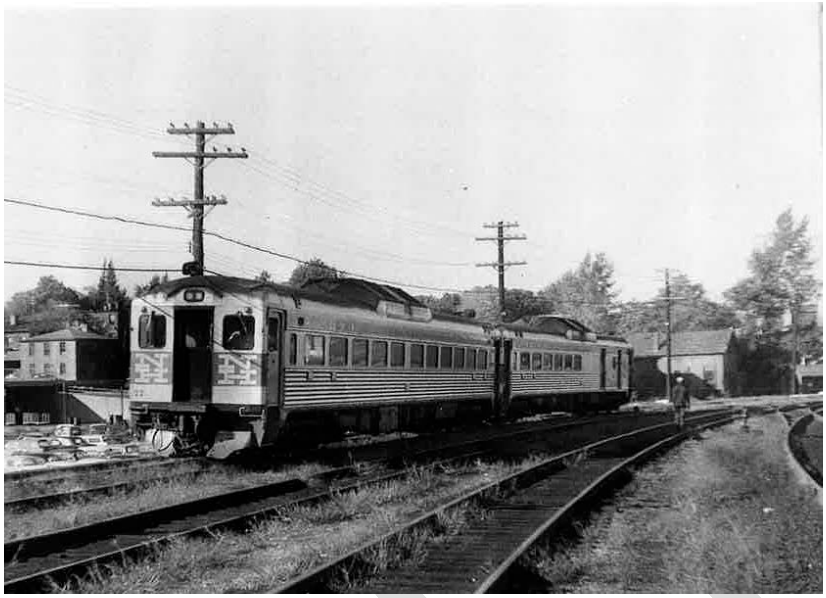


Figure 1: DMU types

DMUs are not new to the US. America's Classic DMU was the Budd Company's Rail Diesel Car (RDC). RDCs were the rail industry's response to dwindling ridership in the 1940's and 50's. It was a Budd RDC that is known to be the last passenger rail equipment operating on the Waterbury Secondary.



Original DMU equipment operating on Waterbury Secondary, 1957. Photo by Jack Swanberg

DMUs typically consist of two ‘married pairs’[1] that can be upwards of 100 feet long and carry 75-110 passengers seated per cab with up to an additional 50-100 standees. Their tight turning radius is in the range of 130-250 feet depending on the manufacturer. While they can operate at speeds up to 125 mph, they typically limit speeds to 55-79 mph. DMUs can accelerate and decelerate at greater speeds than their locomotive counterpart, which makes them ideal when stations are located close together. Improved acceleration/deceleration and better braking ability relates to better travel times and on-time performance. DMUs using “clean diesel” technology are more environmentally friendly than other diesel modes, as they emit less particulate matter, NOx and CO2 than a locomotive. DMU’s would be subject to tighter EPA regulations than locomotives due to their diesel engine classification. They are required to meet EPA Tier IV emissions requirements, a more stringent regulation than conventional diesel locomotives. Overall, DMUs are more energy efficient due to the lower fuel consumption and they produce substantially lower noise than a diesel locomotive. A study conducted by Sonoma-Marin Area Rail Transit, when conducting their alternative vehicle analysis project, found that DMUs could save $1.5 million per year in fuel costs compared to locomotive hauled trains. These shorter vehicles require shorter station platforms and smaller yards compared to locomotive-hauled trains, which further reduces the capital cost to construct. Overall, DMUs allow for more precise matching of passenger demand to capacity and more frequency at a lower cost than commuter rail.

The following commuter rail lines have been considered during the evaluation of implementing service using DMU vehicles: Waterbury Branch; Waterbury Secondary – (Pam Am Southern line); and the New Haven-Hartford-Springfield Line.

[1] [1] ‘Married’ pairs refers to twin units of railroad cars which are coupled together and perform as a single unit; In the U.S. these are often referred to as married pairs. For most DMU married pairs, there is only one diesel engine per car, making it difficult to operate at regular speeds if one engine fails.

Central CT Rail Corridor (also known as the Waterbury Secondary)

The Waterbury Secondary is a 24-mile freight rail line running between Waterbury and Berlin. There are 21 at-grade crossings along the line, which is currently providing freight-only rail service to six-to-eight active freight customers. The DMU equipment would follow the schedule for the conventional rail equipment. This was prepared for the Central CT Rail Study for proposed passenger shuttle and through service on the line that would allow for service every half hour in the morning and evening peak hours, and hourly service during the off-peak. There would be six station stops, Berlin, New Britain, Plainville, Bristol, Plymouth and Waterbury, with connecting service to Hartford, New Haven and Bridgeport.

Waterbury Branch

The Waterbury Branch covers 28-miles of single-track commuter rail from the City of Waterbury to Bridgeport, with a total of 7 stations. Average daily ridership on the Waterbury Branch is approximately 1,000 rides per day. There are planned updates to the Branch which include the addition of a new signal system (there is no signal system currently). The lower ridership and potential shuttle type service makes it a good candidate for DMU-type service. Currently, there are seven roundtrip trains per weekday on the WBL and six on weekends, using three train sets cycled out of the Stamford yard for service on the Waterbury Branch.
Rolling stock equipment typically includes one Brookville locomotive and two-three Bombardier coaches. In terms of compatibility with DMU equipment, there are no known obstacles to the operation of DMUs on the Waterbury Branch. Compliant DMU equipment could operate on the Branch as two pairs (4 total cars) or as a two-car set. Operation beyond the Waterbury Branch to New Haven or Bridgeport could have an advantage from a cost standpoint, as the Passenger Rail Investment and Improvement Act of 2008 (PRIAA) bases payment for operations on the Amtrak mainline on the number of vehicles in the consist for CTDOT equipment operating on their line. A shorter consist would mean a lower PRIIA related cost.

New Haven Hartford Springfield (the Hartford Line)

In this report, the viability of adding DMUs to the existing fleet of CTDOT equipment is evaluated based on the following criteria compared to the existing operation of conventional commuter rail equipment:

- Capital and Operating costs
- Travel times
- Equipment consists (number of vehicles required)
- Energy efficiency
- Reliability
- FRA compliance - requirements such as crash worthiness
- Compatibility with existing equipment and maintenance facilities

1.2.1 FRA Compliance:

Many of the challenges associated with operating a DMU on shared track with FRA-compliant trains (freight and intercity rail) stem from the FRA Code of Federal Regulations 49 Part 238, which specify crash worthiness. The crashworthiness standard classifies DMUs as passenger equipment and therefore must comply with the regulations on federal standards for passenger equipment safety. They are only permitted to share track if they meet the standards for inspection, testing, and maintenance; otherwise, a waiver must be obtained. To meet these requirements, substantial weight must be added to accommodate the equipment and materials for crashworthiness. The extra weight decreases acceleration/deceleration requiring more time to stop, slower speeds and farther station spacing, which all translate into higher operating costs.

When equipment is not FRA compliant a waiver must be obtained for temporal separation if they are to share the tracks with compliant equipment. Temporal separations limit the hours of operation. It can also cause issues with right of way width and station design. DMU vehicles are often narrower and require level platform boarding with minimal gaps per ADA regulations, requiring the platforms to extend into the track area. Some systems have addressed this by adding ramps that can be extended from the DMU to meet the platform, or by creating gangplanks on the platform that can be raised and lowered during the separation or by adding gauntlet tracks.

Other challenges include Buy America requirements, whereby 60% or more of the end product be built in the United States in order to receive federal funding. Typically, manufacturers not already producing equipment in the United States will set up a facility somewhere in the US to assemble and test the final product. For example, Sonoma-Marin Area Transit (SMART) is procuring rail cars from Nippon Sharyo, a Japanese company, so they established a plant in Rochelle, IL to meet Buy America requirements. Nippon will be manufacturing the prototype in Japan and then dissembling it to be shipped to their United States (US) facility where it will be reassembled and tested. If it meets the testing requirements, the rest of the components for the rail cars will be manufactured in Japan and then assembled in the US. In recent years, waivers have been granted for specific parts or assemblies not available in the US.

1.3 Methodological Approach

1.3.1 Key Considerations:

The following considerations were selected to create a framework which guided the development of alternatives for the corridor. First, the proposed system must only use FRA-compatible equipment. Using compliant equipment will limit the number of obstacles in implementing service as opposed to non-compliant equipment which would require a lengthy process of obtaining necessary waivers. Second, DMU equipment must be compatible with mainline operations; otherwise, the system may only operate as a shuttle on branch lines. And lastly, the system must be compatible with CTDOT's existing rail vehicle maintenance program, with some modifications.

1.3.2 Factors considered to assess potential deployment of DMUs:

While the framework provided a guide in the development of alternatives, the analysis of alternatives was guided by a variety of qualitative and quantitative factors. One of the most influential factors regards the overall cost of the system; this includes capital, operating and maintenance costs which give a better idea of the short-term and long-term costs associated with deploying DMU service. Other factors considered include FRA safety compliance, compatibility with existing equipment, technology, and market availability, vehicle performance such as fuel economy and emissions, operational capacity, infrastructure improvements required on the tracks and at stations, passenger acceptance, and community impact, and the maintenance of the fleet.

1.3.3 Operator Experience

A key component in the analysis of alternatives and the development of this report has been communication with commuter rail operators who have used or are in the process of procuring DMUs for service. Conversations with these agencies have provided valuable information on the implementation of service, acquisition of DMU vehicles, capital, operating and maintenance costs, as well as any lessons learned from challenges along the way. The following public transportation (with commuter rail service) operators were contacted during this study: NJ River Line (New Jersey); Capitol Metro (Austin); A-Train (Denton County Transportation Authority, TX); Westside Express Service Commuter Rail (TriMet, Portland, OR); Sprinter (North County Transit District, San Diego, CA). Additional systems, including Metrolinx in Toronto, Canada and SMART Sonoma Marin, were also reviewed as they represent systems in development or with DMUs in operation for less than one year. Topics discussed with these operators are further explored in the case studies presented in Chapter 4 of this report.

Chapter 2. Federal Railroad Administration (FRA)

2.1 Safety History and Context

In most states, the Federal Railroad Administration (FRA) oversees standards for passenger equipment safety, per the Code of Federal Regulations 49 Part 238, Passenger Equipment Safety Standards, which was added in 1999 and subsequently updated. These regulations specify the standards, as well as inspection, testing, and maintenance requirements. Powered rail cars like DMUs are considered to be Passenger Equipment and must comply with the inspection testing and maintenance requirements.

The joint use of tracks for DMUs and other operation types is not a new idea in the United States. Over time, DMUs have evolved to include Light Rail Vehicles, but resurgence has occurred in diesel. Many of the early DMU trains were FRA compliant in accordance with the laws and standards of their time, but the laws have changed. In Europe, DMUs are more commonly used but governed under less strict standards. In an effort to bring back DMUs to the US, a demonstration effort was undertaken by Amtrak in the mid-1990's. Amtrak conducted a tour throughout the US and Canada using Siemens "RegioSprinter" DMU, which was not FRA compliant. They had to obtain an FRA waiver and implement several safety measures along the way. FRA has issued many waivers for joint passenger and freight rail use, however some systems require time or temporal separation measures in accordance with 49 CFR part 211 subpart C, as well as physical separation measures designed to minimize the incidence of fleet mixing through the use of switch point derails and signal system and special operating rules and instructions.

The first law governing railroad safety was in 1893 and was the Safety Appliance Act, which required airbrakes and automatic couplers on all trains. This is reported to have decreased accidents significantly. In 1938 title 49 of the Code of Federal Regulations (CFR) governing transportation and railroads was established. This law established rules governing safety requirements for railroads. Until the FRA was established under Chapter II of Title 49, the Interstate Commerce Commission (ICC) was the railroad regulatory agency. They regulated commerce and some aspects of safety. In 1947, the ICC ordered that all trains traveling in excess of 80 MPH must install automatic train stop, and automatic train control equipment. This effectively limited the speed to 79 MPH or less. This restriction still applies today. In 1966, the FRA was created by congress to oversee and enforce rail safety regulations, most of which are found in title 49. Chapter II of the 49 CFR was established in 1980 including part 229, which governed railroad locomotive safety standards. Part 229 governed passenger rail until Part 238 – Passenger Equipment Safety Standards was added. These laws helped reduce train accidents by 80% between 1980 and 2014. Between 2000, when Part 238 was established, and 2014 train accidents were down 44%[2]. The most recent piece of legislation surrounding safety is the Rail Safety Improvement Act of 2008 which mandates positive train control.

[2] https://www.aar.org/BackgroundPapers/Railroads%20Moving%20America%20Safely.pdf

2.2 Compliance Guidelines (49 CFR 238, as amended)

CFR Part 238 describes the minimum safety standards for railroad passenger equipment. Passenger equipment is defined in Part 238.5 as:

> (1) All powered and unpowered passenger cars, locomotives used to haul a passenger car, and any other rail rolling equipment used in a train with one or more passenger cars. Passenger equipment includes —
>
> > (i) A passenger coach,
> > (ii) A cab car,
> > (iii) A MU locomotive.
> > (iv) A locomotive not intended to provide transportation for a member of the public that is used to power a passenger train, and
> > (v) Any non-self-propelled vehicle used in a passenger train, including an express car, baggage car, mail car, freight car, or a private car.

The definition clearly includes DMU as well as other rail modes. Subpart C of the CFR states all passenger equipment is subject to the structural standard lied within 49 CFR under passenger equipment is exclusively used as a rail line with no public highway/rail crossing grades, no freight traffic, only passenger equipment of compatible design is used and trains do not exceed 79 MPH. This is why light rail and streetcars are not subject to part 238.

Part 238.203 governing static end strength is the most frequently referenced rule in regards to DMU crashworthiness. *"Except as further specified in this paragraph or in paragraph (d), on or after November 8, 1999, all passenger equipment shall resist a minimum static end load of 800,000 pounds applied on the line of draft without permanent deformation of the body structure."* There are several other structural requirements that must be met including but not limited to:

- **238.205 Anti Climbing Mechanism**: "forward and rear ends an anti-climbing mechanism capable of resisting an upward or downward vertical force of 100,000 pounds without failure."
- **238.211 Collision Posts:** "Each collision post shall have an ultimate longitudinal shear strength of not less than 300,000 pounds at a point even with the top of the underframe member to which it is attached."
- **238.213 Corner Posts:** "A 30,000-pound horizontal force applied at a point 18 inches above the top of the underframe, without permanent deformation of either the post or its supporting car body structure."
- **238.215 Rollover strength:** "Each passenger car shall be designed to rest on its side and be uniformly supported at the top ("roof rail"), the bottom cords ("side sill") of the side frame, and, if bi-level, the intermediate floor rail."
- **238.217 Side Structure:** Impact strength

2.3 FRA Waiver Process

In order to operate FRA non-compliant equipment on the same tracks as compliant equipment, a waiver must be completed per 49 CFR part 211 subpart C. The waiver request is for exemption of non-compliance from certain requirements of the standards. The waiver includes the parties involved, nature of the relief request, regulatory provisions included and the petitioner's argument in favor of relief. In general, there are two types of waivers: alternative vehicle technology and temporal separation. To be granted a waiver by the FRA railroad safety board it must be "in the public interest" and must not be "inconsistent with railroad safety". All waiver petitions are published in the federal register for a 45 day comment period. It can then take up to 4-6 months before a decision is made and even more if it is a significant waiver.

Denton County Transportation Authority (DCTA) was the first successful waiver for alternative vehicle technology to operate non-compliant equipment in concurrence with compliant. DCTA submitted two waivers to operate their Stadler GTW 2/6 DMUs which meet European safety standards but not the US. The first was a waiver for certain provisions of title 49 pertaining to Part 238 (passenger equipment standards), Part 229 (railroad locomotive safety standards), Part 231 (railroad safety appliance standards) and Part 239 (passenger train emergency preparedness. The second waiver was to test the Stadler DMUs in the same yard as the Budd RDC compliant equipment and to operate and test the Stadler DMUs on out of service tracks. It took 15 months for the waiver to be granted from the time it was submitted to the FRA. Prior to submitting the petition DCTA worked closely with the FRA, Stadler, and APTA in order to be granted the waiver.

New regulations are being formalized as "Alternative Crash Emergency Management" for equipment that has gone through the rigorous testing and received a waiver. The Notice of Proposed Rulemaking (NRPM) has been working with the FRA Railroad Safety Advisory Committee to broaden the types of vehicles which are deemed compliant. Currently, the crashworthiness data is analyzed at the Volpe Transportation Center in Boston, MA but future DMU compliance testing would be undertaken at the transportation Test Center in Pueblo, New Mexico.

Chapter 3. DMU Equipment & Infrastructure

3.1 Equipment Types

3.1.1 DMU/EMU

Electric Multiple Units (EMU) and Diesel Multiple Units (DMU) are both self-propelled vehicles but vary in their power sources. EMUs rely on energy supplied by an off-vehicle power supply source and distribution system, such as overhead catenary. DMUs have multiple onboard diesel engines for power. This design feature allows for the failure of one engine without significantly impacting route performance. Both are typically lighter in weight than locomotive-hauled coaches (LHC) and have good accelerations. DMUs are ideal for feeder service, off-peak service, or to replace LHC with more frequent service. A world survey of DMU operations by Metrolinkx showed that the breakeven point to operate a DMU verse an LHC is a five car set (Figure 2)[3].

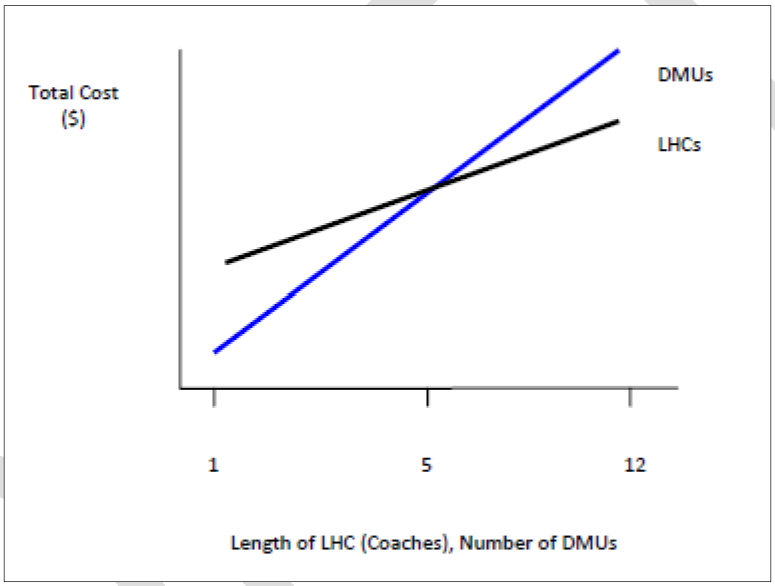


Figure 2: Plot of Total (Cap + O&M) Cost vs. Length

3.1.2 Vehicle Specs

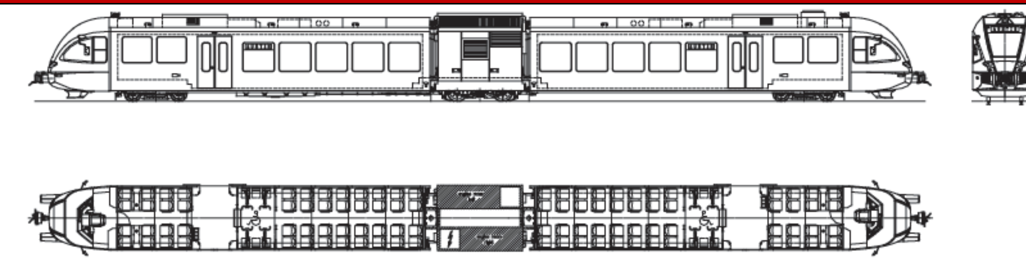
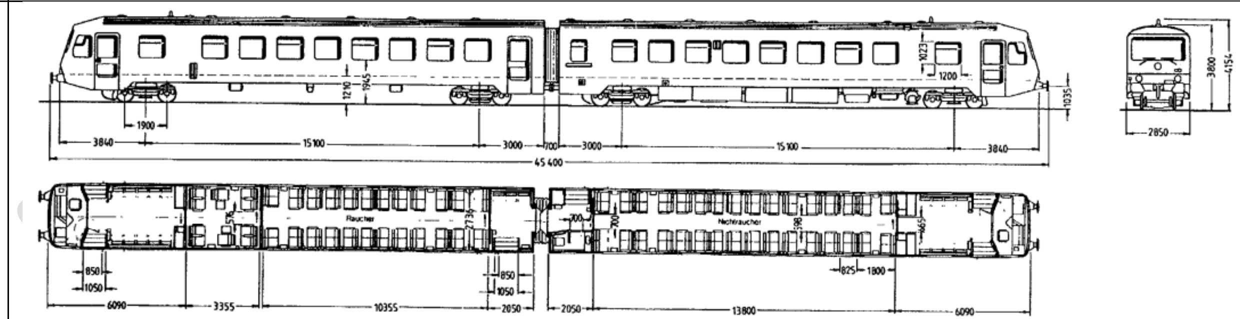
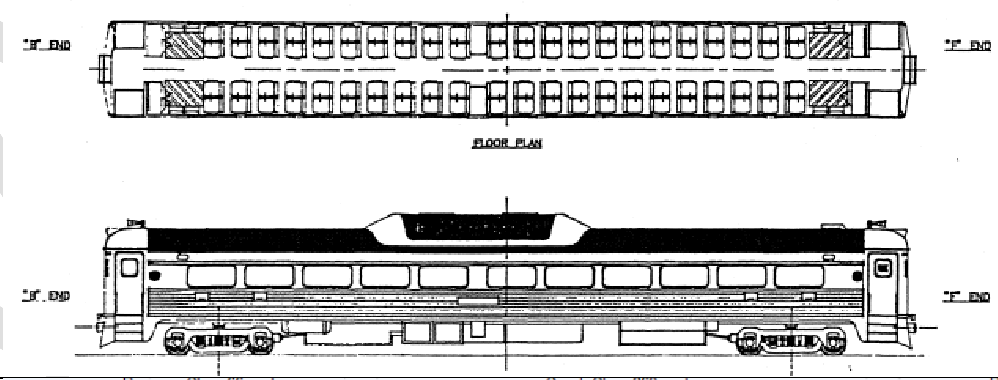
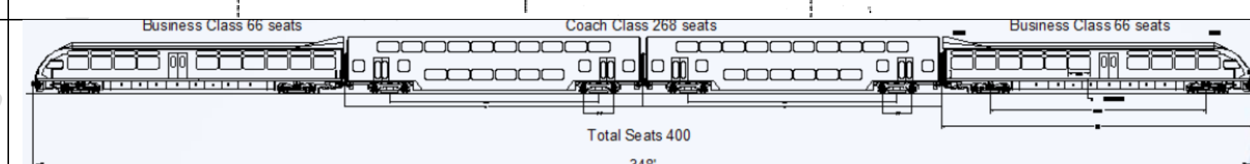
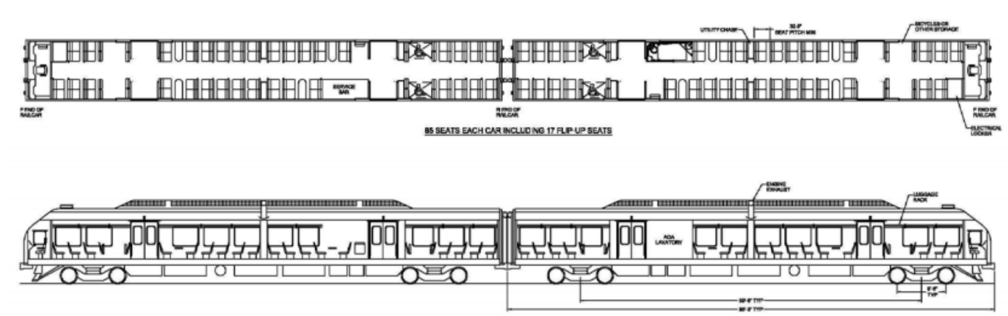
When considering the vehicle specification compliance with the ADA, EPA Tier 4 requirements for emissions and FRA, structural standards must be evaluated in conjunction with the physical requirements of the vehicle. There is a broad range of DMU vehicles with varying characteristics. They can be either single or double decked and consist of a two-car trainset (married pair or articulated) or two powered cabs with 1-4 unpowered coach cabs. The vehicle design though must be compatible with the other train operations on the track; there can be clearance issues from passing freight trains. In some instances, gap fillers are used that are raised at specific times for freight services, and directly line up with DMU doors, which have their own gap filler bridge plates that deploy automatically when doors open. Typical DMU vehicles can seat 75-110 per cab with up to an additional 50-100 standees. Vehicles are at least 9’ 4” and as wide as 10’ feet and can weigh 300,000 to 320,000 pounds (300-320

[3] http://www.gotransit.com/electrification/en/current_study/Appendix%20Files/Appendix%204.pdf

kilopoundsklbs). To be FRA compliant the car body is usually made of stainless steel. FRA regulations also state that the typical exterior moving noise emission at 100 feet is less than 90 dB.

DMU vehicles which are FRA-compliant are heavier than non-compliant. For instance trucks for compliant DMUs are 25% heavier than non-compliant.

While there are many DMU manufacturers and models, the table below lists some of the technical specs for the major models and manufacturers. Following that is a list of all known suppliers and potential suppliers of DMU equipment.

DMU	Length	Passenger capacity	Floor height	Acceleration	Declaration	Max Speed	
Stadler GTW	134' 1.8" for married pair	108 seated, 92 standing	Low floor	2.03 mph/s	2.9 mph/s service 5.4 mph/s emergency 4.9 mph/s Max	75 MPH	
Siemens Desire	136' 9"	98 seated, 110 standing	Low Floor	2.2 mph/s	2.6 mph/s service 4.85 mph/s Emergency	75 MPH	
Budd RDC	85'	90 seated 50 standing	High Floor	1.4 mph/s	2.8 mph/s service 3.5 mph/s emergency	85MPH	
US Rail Car/Colorado Railcar	89' per cab,	73 seated 99 standing	High floor	1.45 mph/s	2.0 mph/s Service 2.5 mph/s Emergency	90 MPH	
Nippon Sharyo	85' per car	79 seated, 80 standing	Low floor	0.78 mph/s	2.1 mphps service 2.8 mphps Emergency	79 MPH	

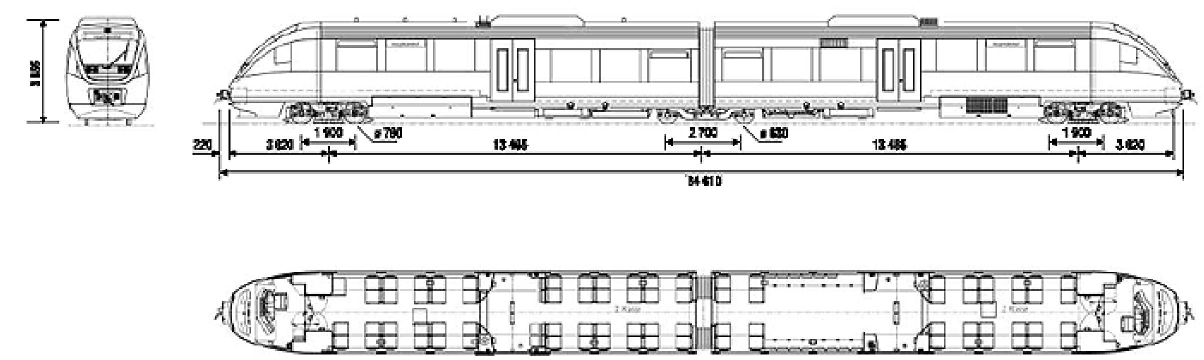
Bombardier TALENT Class	113’ 7”	96 seated, 110 standing	Low floor	0.96 mph/s		75 MPH	

Figure 3: Vehicle Specs

3.1.3 Manufacturers

There are currently approximately 20 manufacturers in the world of DMU equipment, seven of which are developing, have in production, or have indicated they would make FRA-compliant equipment. Five of the manufacturers (Hyundai Rotem, Brookville Equipment Corporation, Nippon Sharyo, Siemens Corp and U.S. Rail Car LLC) have indicated that they could have manufacturing/assembly facilities in the United States, to accommodate FTA Buy America requirements for rolling stock. Budd RDC, which is FRA compliant, is no longer in production but many cars have been refurbished and are in use. ADTranz developed the Flexliner to meet FRA compliance when it was bought out by Bombardier. The Flexliner DMU had been in operation in Sweden and Denmark since 1989.

Table 1. DMU Manufacturers

Manufacturer	Model	Location	FRA Compliant	Other Notes
Brookville Equipment Corp	DMU	United States	Yes	Predominately make LRT
Bombardier	DMU rail car	Montreal	Yes	In development
Nippon Sharyo/Sumitomo	Rail Diesel Car	China	Yes	FRA compliant vehicles in service 2015 in Toronto
Siemens Corp	VT 610/628	Germany	Yes	In development
Stadler Rail	GTW	Switzerland	Yes	FRA waiver granted to DCTA
US Railcar LLC	DMU	United States	Yes	
Hyundai Rotem	DMU	South Korea	Yes	Won bid to make for TTC but project never took off
ABB	Class 158 Express	United Kingdom	No	
Faur S.A.		Romania	No	
GEC Alsthom	Alice	France	No	Now Alsthom
Goninan	Sprinter	Australia	No	
Hunslet Transportation Projects, Ltd.		United Kingdom	No	
Hunslet-Barclay, Ltd.		United Kingdom	No	
Luhanskteplovoz	DMU	Ukraine	No	
Materfer	CMM 400-2	Argentina	No	
Metrowagonmash	RA-2	Russia	No	
Niigata Transys	KiHa	Japan	No	
Pesa SA	Atribo	Poland	No	
No longer in production or has been bought out				
Budd Rail Diesel Car	RDC	United States	Yes	No longer exists
ADtranz	Flexliner	Germany	Yes	Now part of Bombardier
Fiat Ferroviaria	Y1R	Italy	No	Bought by Alsthom
SLM	Futuro	Switzerland/France	No	Now Stadler
Linke-Hofmann-Busch GmbH		Germany	No	Bought by Alsthom
GEC LHB	Lint	France	No	Bought by Alsthom
Fuji Heavy Industries Ltd.		Japan	No	Discontinued rail production

3.2 Infrastructure and Operational Considerations

3.2.1 Lateral Clearance

Managing DMU lateral clearance for passenger platforms and freight trains has been a challenge. Strategies have included gauntlet tracks, movable platform edges and low floor vehicles. In cases where there is not a temporal separation and wider freight trains use the corridor gauntlet tracks are used at stations. Gauntlet tracks allow 2 sets of rails to be installed on a single track bed that run parallel to each other. This allows for the passenger rail to use the tracks closer to the platform and reduce the gap and the freight rail to use the pair of rails furthest away from the platform.

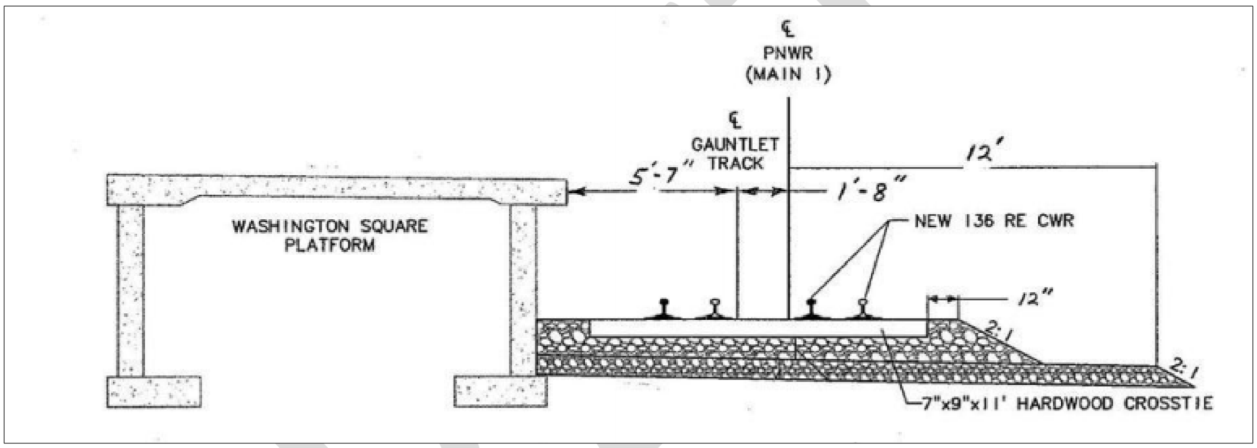


Figure 4: Gauntlet Track

3.2.2 Platforms

In some cases, passenger platforms must be set back from the profile of a station-dwelling passenger train, in order to allow wider freight trains to use the track at other times. In these cases, a mechanical "drawbridge" or platform gap filler, of a variety of types, is used to fill in the gap between the passenger door and the platform in order to meet the ADA universal design requirements that there be no more than a 3" horizontal gap and 5/8" vertical gap. Platforms with level boarding must be served by vehicles with active suspension systems that maintain the vehicle height under varying load conditions. Many DMU vehicles, such as the Stadler GTW or Colorado Railcar, use an airbag suspension system.

Future challenges with platforms may arise when vehicles need to be replaced are added due to service expansion. When a platform is designed to a specific vehicle it limits the selection of vehicles that can be used. This has been seen in systems which began service operating with Budd RDCs before their newer equipment was available.

3.2.3 Grade Crossings

When lighter vehicles operate on tracks at lower densities, rust has been known to build up, which can cause poor shunting.[4] To address this some railroads have used spring-mounted brushes[5],, however some DMU manufacturers have alternate methods to improve track circuit shunting for grade crossings warning devices and for the signal & train control system.

[4] Shunting can be described as a lack of an electrical connection is a rail safety concern as it– can allow a train to disappear from a railroad dispatcher's computer screen, raising the possibility of a collision if two trains are cleared to travel on the same tracks, or inconsistent shunting can cause grade crossing warning devices (flashers and gates) to not detect the presence of a train.

[5] https://www.arema.org/files/library/2013_Conference_Proceedings/Diesel_Multiple_Units_in_North_America-Trends_in_Construction-Maintenance-Operating_Practices.pdf

Chapter 4. DMU Experience in the United States

4.1 Overview

Budd Company manufactured 398 RDCs between 1949 and 1962 and many refurbished ones are still in use today. There were five different models ranging in length from 73 to 85 feet. The base model, without a baggage area, could carry up to 90 passengers seated. They were constructed using stainless steel, steel T framed and are powered by two Detroit diesel series 110 engines mounted under the floor. Due to cutbacks in passenger service by many railroads, orders for the RDCs started to dwindle and Budd Company went out of service. The last RDC in operation by a public transit provider, until the recent resurgence, was by the Maryland MTA in 1993. After over a ten year hiatus in operations of the Budd RDC, some agencies began to start operating them again. Today almost half of the original RDCs are still being used as secondary's on mainline services, on branch lines and as spares for systems that operate modern DMUs on transit lines. One of the largest purchasers of the RDC was the New Nork, New Haven, and Hartford Railway, which operated the 40 cars along what is now known as the Metro North New Haven Line including the Waterbury branch. Others were purchased by the New York Central Railroad and used on the Boston to Albany rail corridor that runs through Springfield, MA. Many of the Budd RDC vehicles were acquired by Amtrak shortly after their formation in 1971, which used them in the Northeast until the 1990s. They were operated on the New Haven-Springfield route amongst other corridors. Amtrak no-longer uses them. Today old New Haven RR RDC's are used on the Trinity Railway Express between Dallas and Fort Worth, Texas, and as spares for the Portland, OR WES line.

Figure 5: BUDD RDC car at the Danbury Railway Museum

4.2 Selected Case Studies

This section presents insights gained through telephone interviews with agency staff, and/or available information on DMUs operating in the US and Canada.

4.2.1 River Line - NJ Transit - Camden –Trenton, NJ

System Characteristics

The River Line operates along a 34 mile corridor from Trenton to Camden, NJ, stopping at 21 stations. The corridor (30 of the 34 miles) was purchased from Conrail, which used it as its

Bordentown Secondary, in 1999 for $67.5 million[6]. As a result of the purchase NJ Transit and Conrail entered into an agreement for temporal separation. NJ transit has the right to operate passenger service from 6 AM to 10 PM and Saturday evening into Sunday morning 1 AM because Conrail does not have Sunday operations.

Figure 6: River Line

The new service uses a fleet of 20 Stadler GTW DMU units, which are FRA non-compliant. The Stadler vehicles were built by Stadler Rail Group in Switzerland. Each car can hold up to 70 passengers seated plus 94 standing and can reach speeds up to 55 MPH. At full capacity, the maximum acceleration is 2.03 mphps and deceleration is 4.47mphps[7] therefore, if the vehicle was at top speed it would take 13.3 seconds and 525 feet to come to a complete stop. The Stadler GTW DMU unit has a turning radius of 40 meters (131 feet), which makes it suitable for street running on certain sections of the corridor.

Operations have been contracted out to the Southern New Jersey Rail Group[8] as part of the design, build, operate and maintain contract. Service hours are limited to 6 AM-10 PM due to the temporal separation, which NJ transit believes puts a squeeze on service. Since the line is single and double tracked in various segments, 15 minute peak service and 30 minute mid-day service are the maximum that can be operated. Trains must meet on a regular schedule in the right places to pass, which locks NJ transit into the headways they have. Scheduled travel time for the entire route is 65 minutes[9] and the daily average ridership is slightly over 9,000[10]. On time performance data for the route is 96.2%[11]

Total System Cost

The River Line was constructed using a design, build, operate and maintain contract, which was awarded to Southern New Jersey Rail Group. The total contract was for $615 million of which $452 was to design and build the project[12]. Reports estimate though that the final cost was closer to $1 billion[13]. This did not include the cost of $67.5 million NJ Transit had to pay to Conrail for track rights between 6 AM and 10 PM. In order to keep the project going, the state borrowed and bonded additional money and now pays $48 million a year in debt service. The cost does

[6] http://www.masstransitmag.com/article/10221262/unique-rail
[7] http://www.stadlerrail.com/media/uploads/factsheets/GTW_SNJ_en.pdf
[8] http://njtransit.com/tm/tm_servlet.srv?hdnPageAction=PressReleaseTo&PRESS_RELEASE_ID=742
[9] https://www.njtransit.com/pdf/bus/T0343.pdf
[10] http://www.njtransit.com/pdf/FactsAtaGlance.pdf
[11] http://njtransit.com/AR/flip/index.html#24
[12] http://articles.philly.com/1998-11-13/news/25734047_1_commuter-rail-bid-rail-line
[13] http://www.njtransit.com/tm/tm_servlet.srv?hdnPageAction=Project006To

include the price for the purchase of the 20 DMU units. The project received no federal funding and was funded through a state gas tax[14].

Annual Operating Costs

National Transit Database (NTD) reports show that the cost to operate the River Line was $33,542,255 for FY 2013, this equates to a cost per revenue mile of $27.26 and cost per revenue hour of $674.32. General administration accounted for 15% of the cost, operations 64% and the remaining was maintenance. The original contract (for 10 years) to operate and maintain (OM) the system was awarded to Southern New Jersey Rail Group (SNJRG) a subsidiary of Bombardier for $163 million. In 2014, the contract was up and NJ Transit released a new OM RFP which was again awarded to SNJRG. This time, the contract was for 20 years (15 base plus 5 year renewal option) and was for almost three times the original. The new contract was for $443,420,739.41[15] and included $41.9 million for capital funding improvements.

Annual Maintenance Costs

Vehicle maintenance is done it its own complex near the 36th Street Station and is included in the SNJRG OM contract. The contract includes a Capital Asset Replacement Program which requires the contractor to maintain the capital assets in a state-of-good-repair. NTD data shows that $4,981,568 was spent on vehicle maintenance and $992,627 on non-vehicle maintenance in FY2013. Non-vehicle maintenance includes such things as facility, station, and track maintenance. Overall the system has been operating smoothly and there have been no major mechanical issues aside from minor propulsion issues. The issue was dealt with but it is unclear if it was a result of it being specific to DMUs or if a similar issue might have occurred regardless of the system.

History/Background

More than 40 years after passenger service had been discontinued on the corridor in 1963[16], service was restored in 2004 after decades of planning. NJ Transit was the first system to operate a DMU service in the United Sates in over a decade. The project was championed by Senator C. William Haines who pushed for rail service along the Delaware River between Trenton and Camden. He introduced legislation in 1996 that required NJ Transit to study the feasibility of rail along the corridor despite the contrary findings from the recent Major Investment Study that proposed running the rail from Camden along Marne Highway[17].

The decision to use DMUs as opposed to light rail or alternative rail modes came primarily down to cost. Early on NJ Transit realized they could not get federal funding for the process because they could not meet some of the federal process criteria, they did not believe they could meet the ridership requirements. Thus, the decision was made to fund it at the state level to try and encourage economic development in the corridor. This decision put pressure to reduce costs and one of the capital elements, where cost savings was found, was through the elimination of the

[14] http://www.apta.com/passengertransport/Documents/archive_254.htm
[15] http://www.njtransit.com/pdf/6-11-2014_BoardItems_final.pdf
[16] http://www.nytimes.com/1996/04/28/nyregion/road-and-rail-trolley-urged-for-a-limping-old-freight-line.html
[17] http://articles.philly.com/2003-07-28/news/25453628_1_rail-line-light-rail-major-investment-study

catenary system. To reduce capital and maintenance costs even further, over 50% of the line is single tracked[18].

Relevant Lessons Learned

Lessons learned include the following:

- Temporal separation limits service hours.
- If all of the federal process criteria cannot be met then federal funding cannot be received.
- Single track with passings requiresnt headways that may not be as frequent as desired.
- Projects like these need a political champion to get it approved.
- If freight rail breaks down overnight and cannot be fixed and moved by the morning, the DMUs would not be allowed to operate and service would be halted.

4.2.2 Indigo Line - MBTA – Boston, MA

The MBTA had been looking at procuring 30 DMUs as part of the 5 year capital improvement plan. DMU service was proposed on the Fairmont Line upgrades, the proposed Indigo line, a 9.2 mile track from Boston to Readville and service between Chelsea and Lynn. The Indigo Line is part of the Fairmont Line upgrade which is renovating and adding stations. Currently, the corridor is undergoing a planning initiative to conduct a comprehensive plan for the corridor.

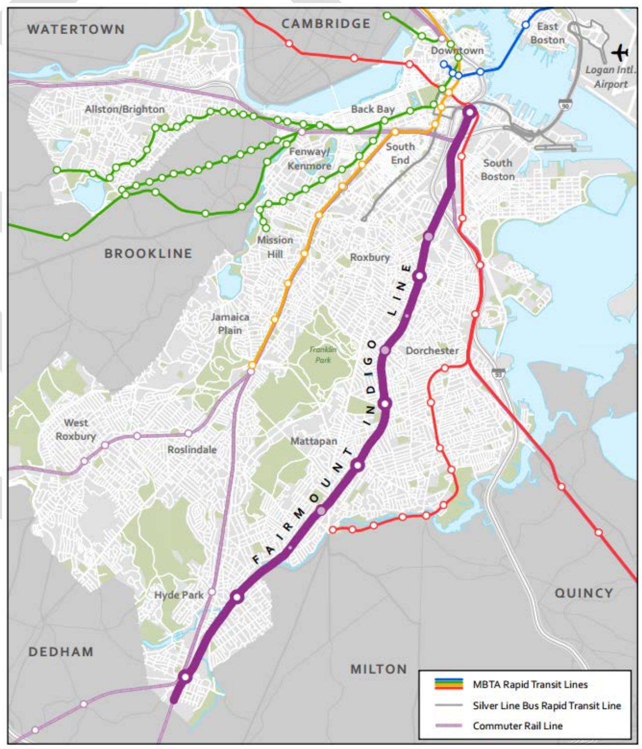


Figure 7: Proposed Indigo Line

Funding for the FY16 budget for the project was cut in June 2015 by Gov. Baker. The MBTA anticipates that the current procurement process may drag on and is not likely to move forward due to costs. It is estimated that approximately $250 million would be needed to procure the vehicles and $450 million to improve existing infrastructure.

Relevant Lessons Learned

Lessons learned include the following:

- Political support is needed to ensure funding.
- Infrastructure costs are essentially the same for DMU and conventional rail equipment.

[18] Phone interview with Neal Fitzsimmons, Director of Light Rail Service Planning, and NJ Transit. November 14, 2014

4.2.3 A-Train - DCTA – Denton County, TX

System Characteristics

The A-Train operates along a 21 mile corridor from Denton to Carrolton, TX, it parallels Interstate 35 and stops at 6 stations. The rail line, a former Missouri-Kansas-Texas Railroad, includes an adjacent rail trail. At its southern end, it connects to the Dallas Area Rapid Transit (DART) Green Line. The whole corridor is owned by DART as part of the Green Line. DART purchased the line from the Union Pacific Railroad. Both DART and DCTA directly operate along the line and DART maintains a trackage right agreement with Dallas Garland and Northeastern Railroad (DGNO) for freight operations[19]. There are approximately 3-5 freight trains per week along the corridor[20]. While the equipment was FRA non-compliant, DCTA successfully petitioned for a waiver to operate non-compliant equipment in concurrence with the complaint. The waiver was the first ever alternative vehicle technology waiver granted to use non-compliant cars in active freight corridors without temporal separation. It took 14 months but the waiver was granted. While DCTA was awaiting the approval of the waiver, they operated Budd RDC cars along the line.

Figure 8: A-Line

The new service uses a fleet of 11 Stadler GTW DMU 2/6 articulated rail vehicles. The Stadler vehicles were built by Stadler Rail Group in Switzerland. Each car can hold up to 104 passengers seated plus 96 standing and can reach speeds up to 75 MPH. At full capacity, the

[19] https://www.federalregister.gov/articles/2011/02/10/2011-2920/petition-for-waiver-of-compliance
[20] http://www.apta.com/mc/rail/previous/2011/Presentations/T-LeBeau-FRA-Waivers-An-Alternative-Approach.pdf

maximum acceleration is 1.79 mphps and deceleration is 2.9 mphps[21]. If the vehicle was at top speed it would take 25.6 seconds and 1,278 feet to come to a complete stop under normal braking conditions and 15.9 seconds and 795 feet under emergency braking. The Stadler GTW DMU unit has a turning radius of 40 meters (131 feet), which makes it suitable for street running on certain sections of the corridor.

When DCTA launched the A-Train they partnered with DART and Trinity Railway Express (TRE) for operational efficiencies. Herzog Transit Services had a maintenance contract with DART and were familiar with the Budd RDC cars DCTA was operating in the interim until the Stadler DMUs were approved by the FRA. By sharing overhead, DCTA could reduce the cost and provide more service. Since the line is single and double tracked in various segments, 20 minute peak service and 60 minute mid-day service are the maximum that can be operated. Scheduled travel time for the entire route is 32 minutes[22] and the daily average ridership is slightly over 2,500[23].

Total System Cost

The A-Train capital cost to build stations, rail maintenance facility, and update the track was $193 million plus $73.7 million to procure 11 vehicles. The entire track along the corridor had to be replaced; speeds had been limited to 10 mph because of the poor conditions. Passing sidings had to be added and the signal system improved.

Annual Operating Costs

National Transit Database (NTD) reports show that the cost to operate the A line was $11,319,050 for FY 2013, this equates to a cost per revenue mile of $18.93 and cost per revenue hour of $508.22. General administration accounted for 10% of the cost, operations 79% and the remaining was maintenance. The contract with Herzog for O&M was for $8,430,186 in FY13 and increased by 9.6% for FY14[24].

Annual Maintenance Costs

A new state-of-the-art maintenance facility had to be constructed for the A-Train and is now used as a regional maintenance and dispatch facility to others in the region. The facility had to be capable of maintaining and operating both the Stadler DMUs and the Budd RDCs. A Stadler warranty officer is kept on site in case any problems arise. Overall the system has been operating smoothly and there have been no major mechanical issues. The only mechanical issue has been getting parts. Routine maintenance parts must come from Germany and it takes about two months for the part to arrive, as opposed to days with domestic suppliers.

DCTA has experienced some issues with shunting due to the vehicle's lighter weight, weight distribution, and geography. Part of the line runs through wetland which creates a film residue over the rail. In order to prolong the useful life of the tracks and eliminate material buildups, rail grinding is performed every 2 years. It costs approximately $192,000 to perform this task. In late 2015 DCTA in conjunction with DART, TRE and TexRail formed the Texas Commuter Rail

[21] http://www.stadlerrail.com/media/uploads/factsheets/GDCT0909e.pdf
[22] https://www.dcta.net/routes-schedules/a-train/a-train-schedule
[23] Interview with Jeffrey Bennett
[24] https://www.dcta.net/images/uploads/content_files/2014dctabudget.pdf

Alliance to implement the federally mandated Positive Train Control (PTC). Implementation of PTC began in the winter of 2014/15 and will cost $22.9 million to implement.

History/Background

DCTA was established in 2001 under chapter 460 of the Texas Transportation Code. In 2002, voters approved a ½ cent sales tax to fund the system. In 2004, an alternative analysis was conducted to identify the best and most cost-effective mobility solution of Denton County. The study, which proposed the rail line, was approved by the board. The board then worked with the FTA to ensure the proposed line would meet regulatory requirements. In 2008, the Environmental Impact Determination was completed and construction began. The A-train went into public operation on June 20th, 2011. The first 14 months of service posed many challenges, as DCTA waited for their Stadler GTW DMUs to be given an FRA waiver Budd RDCs were used. The platforms had been designed for low floor vehicles but the Budd cars were not designed for such leaving an 8" vertical between the platform and height of the vehicle. DCTA had to design a temporary steel platform and ramp mounted to the station platform.

The decision to use DMUs as opposed to light rail or alternative rail modes was due to the efficiencies from a shared contract with DART and improved passenger experiences over conventional LHC. The Stadler DMUs provide a smoother ride, have level platform boarding, better acceleration/braking which allows for time savings and shorter headways. The DMUs also have improved fuel efficiency. DCTA also wished to maintain freight activity along the corridor.

Relevant Lessons Learned

Lessons learned include the following:

- Wetlands can cause shunting
- Entering into agreements with others can reduce overhead costs
- Limit the number of at grade crossings
- If seeking an FRA waiver, meet with the FRA and start the process before the vehicles are procured in order to gain support
- Station modifications may be needed if operating different vehicle types in order to have level boarding
- It can be difficult to procure replacement parts for routine maintenance in a timely manner since the vehicles are foreign made
- Local support to approve a tax increase to support the project is a must

4.2.4 Red Line - Capital Metro – Austin, TX

System Characteristics

Capital Metro operates the Red Line, a 32 mile corridor from Austin to Leander, TX, stopping at 9 stations. The equipment is FRA non-compliant but they do have a temporal separation with Watco Company to run passenger rail from 4 AM to 8 PM. Watco runs freight trains between 8 PM and 4 AM and there are usually 2-3 freight trains per week along the corridor.

Figure 9: Metro Rail

The new service uses a fleet of 6 Stadler GTW DMU units, which are FRA non-compliant The Stadler vehicles were built by Stadler Rail Group in Switzerland. Each car can hold up to 96 passengers seated plus 92 standing and can reach speeds up to 75 MPH. At full capacity, the maximum acceleration is 2.03 mphps and deceleration is 2.91 mphps[25] therefore if the vehicle was at top speed it would take 25.6 seconds and 1278 feet to come to a complete stop under normal braking conditions and 15.1 seconds and 755 feet under emergency conditions. The Stadler GTW DMU unit has a turning radius of 40 meters (131 feet), which makes it suitable for street running on certain sections of the corridor.

Operations are contracted out to Herzog as part of the "operate and maintain" contract. Service hours are limited to 4AM - 8PM due to the temporal separation with Watco. Since the line is single and double tracked in various segments and there are a limited number of vehicles 34 minute peak service and 60 minute mid-day service is the maximum that can be operated. Scheduled travel time for the entire route is 59 minutes[26] and the daily average ridership is slightly over 1,500. On time performance data for the route is 98%[27]. Metro does have plans to purchase 4 new rail cars at a cost of $28 million. This will increase capacity by 2,400 passenger trips a day and increase frequency to 15 minutes during the peak. The additional $22 in funding is to construct a larger rail station in downtown Austin[28].

[25] http://www.stadlerrail.com/media/uploads/factsheets/GCAP1007e.pdf
[26] http://www.capmetro.org/schedmap/?svc=2
[27] Interview with Brian Allen of Capitol Metro
[28] http://www.masstransitmag.com/press_release/11542329/tx-capital-metro-awarded-50-million-by-txdot-for-metrorail-improvements

Total System Cost

The capital cost to build stations and update the track was reportedly $72.7 million plus $32.3 million to procure 6 vehicles[29]. Capital costs were used to construct an overpass of the Union Pacific Fright line in order to have grade separation. Costs also include building a railcar maintenance facility, installing crossings and wayside signals, replacing ties and resurfacing the rail[30]. The corridor was originally used for freight by Capital Metro and operated to such standards since commuter rail operates at different speeds and times the signals had to be updated.

Annual Operating Costs

National Transit Database (NTD) reports show that the cost to operate the line was $13,712,449 for FY 2013, this equates to a cost per revenue mile of $49.09 and cost per revenue hour of $1,186. General administration accounted for 25% of the cost, operations 11% and the remaining was maintenance. The operating contract with Herzog is for a five year period (2009-2014) for $61 million including contingency.

Annual Maintenance Costs

Vehicle maintenance is done it its own complex just north of where the rail line crosses I-183. NTD data shows that $7,618,383 was spent on vehicle maintenance and $1,174,409 on Non-vehicle maintenance. Non-vehicle maintenance includes such things as facility, station and track maintenance, fare collection equipment and counting, and communication systems.

History/Background

In 1986, Capital Metro partnered with the City of Austin to purchase the corridor, along with 130 other miles of track from the Austin and Northwestern Railroad[31]. The line was purchased for $9.3 million with funds from the FTA. They then drew up plans for north-south and east-west passenger rail lines. This was a result of 1997 Texas Legislation that mandated Capital Metro hold a referendum on light rail by 2000[32]. The mandate was due to the public controversy about Capitals Metro's management, board, and accountability. The proposal was defeated at the polls. In 2004, Capital Metro presented a scaled down version which was approved at the poles. The Red Line was the first phase of the MetroRail system. Veolia was originally awarded the contract to operate and maintain the line but due to numerous safety issues that pushed the launch date back by two years the contract was terminated and awarded to Herzog in 2009. At the same time, Watco Companies Inc. was awarded the five year contract to operate Capital Metro's freight rail along the corridor for $33 million. They had been operating it since 2007. The passenger service along the line began on March 23, 2010. In 2013 Capital Metro was awarded an $11.3 million TIGER grant that will improve signal timing and reduce delay, add additional siding and double tracking in critical areas, and freight enhancements to increase speeds, improve safety and double capacity[33].

[29] http://www.stadlerrail.com/en/news/2005/09/23/stadler-wins-commuter-rail-car-award-with-capital-/
[30] http://www.metro-magazine.com/management-operations/article/211175/all-systems-go-for-austin-commuter-rail-service
[31] George C. Werner, "AUSTIN AND NORTHWESTERN RAILROAD," *Handbook of Texas Online*(**http://www.tshaonline.org/handbook/online/articles/eqa12**), accessed July 27, 2015. Uploaded on June 9, 2010. Published by the Texas State Historical Association.
[32] http://www.austinchronicle.com/news/2000-10-13/78940/
[33] http://www.capmetro.org/news-item.aspx?id=2636

The decision to use DMUs as opposed to light rail or alternative rail modes was so that Capital Metros freight division could still operate with a temporal separation and ridership projections did not warrant LHC.

Relevant Lessons Learned

Lessons learned include the following:

- Temporal separation limits service hours.
- Using European equipment requires a long time to procure replacement parts.
- If the transit system is not seen in a positive light by the community new projects will never get off the ground.
- A lack of passing sidings and double tracking has resulted in less than desirable headways and increased rail traffic congestion.

4.2.5 Trinity Railway Express – DART/The T – Dallas/Fort Worth, TX

System Characteristics

Trinity Railway Express (TRE) is an interlocal agreement between the Fort Worth Transportation Authority (The T) and Dallas Area Rapid Transit (DART) to provide commuter rail service. The corridor is 34 miles long from Dallas to Fort Worth, TX, stopping at 10 stations. The track consists of a series of single track, passing sidings and occasional double tracking. The equipment is FRA compliant and used along with locomotive haul cars. Two freight carriers, Burlington Northern and Santa Fe Railway (BNSF) Railways and Union Pacific Railroad (UPRR) operate along the entire corridor and Garland & Northeastern Railroad and the Fort Worth & Western Railroad use part of the line.

Figure 10: TRE DMUs

The new service uses a fleet of 13 Budd RDC units, which are FRA compliant as well as 9 diesel locomotives and 25 bi-level coach cabs. The Budd RDC was built by the former Budd Company of Philadelphia between 1949-1962. TRE purchased the RDC units from Via Rail Canada in 1993 and they were remanufactured by GEC Alsthom in Montreal in 1997. Each car can hold up to 96 passengers seated plus 50 standing and can reach speeds up to 85 MPH. Currently, only three of the Budd cars are part of the active fleet, the rest are stored at the TRE maintenance facility as spares.

Operations and maintenance are contracted out to Herzog Transit Services. The initial contract was for train operations and vehicle maintenance only but dispatch for all train traffic was later added to the contract. For Phase II, there was a separate RFP for ROW Maintenance and Capital Improvements. Herzog was awarded that contract. Service hours are 5AM – 11:35PM Monday through Friday, Saturday 5:40AM – 11:35PM and no Sunday service. Since the line is single and double tracked in various segments 30 minute peak service and 60 minute off-peak service is the maximum that can be operated. Scheduled travel time for the entire route is 58-62 minutes[34] and the daily average ridership is slightly over 8,200.

Total System Cost

[34] http://www.trinityrailwayexpress.org/eastboundweekday.html

Construction of the TRE was divided into two phases. Phase I was the 10 mile segment between Dallas and South Irving and Phase 2 the 24 mile segment between South Irving and Fort Worth. Phase I of the project was fully funded with local, Section 5207 and CMAQ funds (Figure 12). Phase 1 was $69.6 to construct and included improvements to the 10 mile stretch of tracks plus 5 additional miles of non-revenue tracks, the purchase of the 13 Budd RDCs, the creation of a train yard and maintenance facility, station development, and land purchases (Figure 11). Each RDC was approximately $2 million, including the rebuild by Althsom.

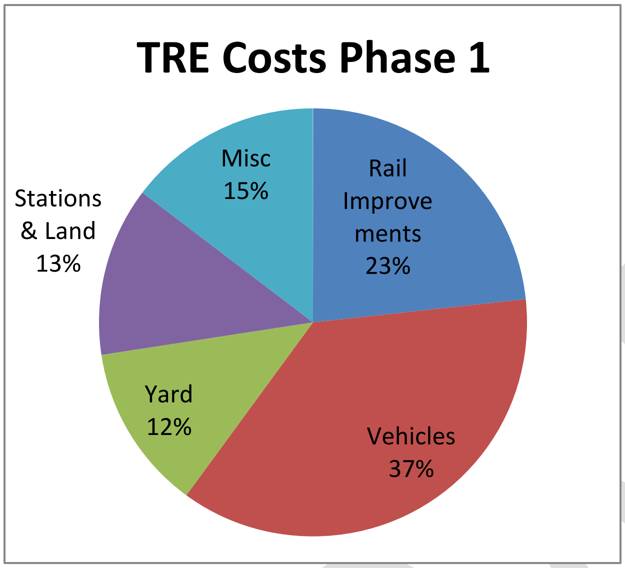


Figure 11: TRE Capital Costs Phase 1

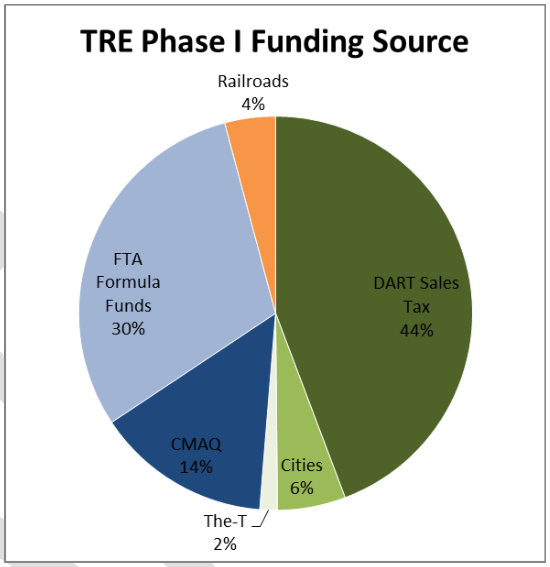


Figure 12: TRE Phase I Funding Sources

Phase II was estimated to cost $188.6[35] million to construct and included purchasing locomotives and coaches, expanding the rail yard, adding stations, and updating the railroad facilities (Figure 13). The project was both federal and locally funded (Figure 14, green indicates local funding sources, blue is federal and orange is other).

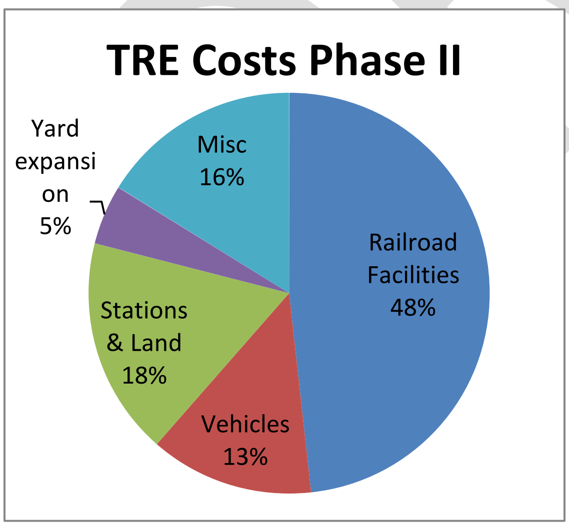


Figure 13: TRE Capital Costs Phase II

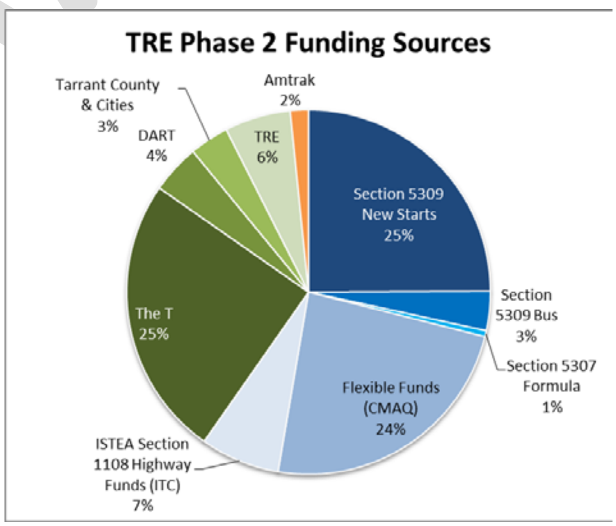


Figure 14: TRE Phase II Funding Sources

[35] http://www.azta.org/images/uploads/handouts/TRE_(Blaydes).pdf

Annual Operating Costs

National Transit Database (NTD) reports show that the combined cost for DART and The T to operate the line was $29,041,219 for FY 2013, this equates to a cost per revenue mile of $25.37 and cost per revenue hour of $587. General administration accounted for 18% of the cost, operations 34% and the remaining was maintenance. Operations and maintenance are contracted out to Herzog Transit Services using a performance-based contract. Payment is based on general fees for administration, maintenance of way, overhead, and the number of train hours and car miles. Herzog is responsible for maintaining the right-of-way, staffing the trains, dispatch on the corridor, and equipment maintenance. The FY 2014 contract with Herzog for operations was for $44,994,916[36].

Annual Maintenance Costs

Vehicle maintenance is done it its own complex slightly west of the West Irving Station. This station is located approximately midway between Dallas and Fort Worth. NTD data shows that $12,432,559 was spent on vehicle maintenance and $10,464,759 on non-vehicle maintenance. Non-vehicle maintenance includes such things as facility, station and track maintenance, fare collection equipment and counting, and communication systems. The contract with Herzog for capital maintenance was for $10,340,509 in FY14

History/Background

TRE rail operates over the form Chicago Rock Island and Pacific Railroad corridor (Rock Island). The corridor was acquired in 1984 by the cities of Dallas & Fort Worth when Rock Island ceased operations and the assets were sold off. In 1994, the Dallas, DART, The T and Fort Worth entered into an interlocal agreement to jointly develop and operate commuter rail on the corridor. In December of 1996, the first segment began operations between Union Station in Dallas and the South Irving Transit Center. Four years later service was extended west to Richland Hills and locomotives and bi-level coach cars were purchased. Until 2000 service was provided solely by the Budd RDC units. Adding the locomotive haul equipment to the fleet provided a cost savings as ridership demand increased[37]. Finally, in 2001 the last segment to Fort Worth was constructed completing the 34 mile corridor[38].

Both parent agencies developed strategic plans to double track the entire length of the corridor and add bi-directional signaling. It soon became clear that to do such improvements would be costly and time-consuming so TRE in conjunction with the freight providers worked to determine where would be the best location add more passing segments and double tracks in order to best increase freight traffic and improve passenger operations. The first step in upgrading the corridor was the improvement of grade crossings and warning devices in 2007. This allowed for the passenger rail to increase from 30 MPH and 79 MPH and freight to operate at 50 MPH. Adding passing sidings further improved travel.

The decision to incorporate DMUs into the fleet was so that freight operations could be maintained.

[36] https://www.dart.org/about/board/boardminutes/boardminutes10sep13.pdf
[37] http://www.apta.com/mc/rail/previous/2010/Papers/Doing-More-with-the-Same-How-the-Trinity-Railway-Express-Increased-Service-without-Increasing-Costs.pdf
[38] http://www.trinityrailwayexpress.org/aboutTRE.html

Relevant Lessons Learned

Lessons learned include the following:

- Must have a good working relationship with the freight provider.
- A lack of passing sidings and double tracking has resulted in less than desirable headways.

4.2.6 TEX Rail – The T - Tarrant County, TX

System Characteristics:

Fort Worth Transportation Authority (The T) has proposed a new commuter rail project, TEX Rail, which will service 10 (2 existing stations) stations along a 27 mile corridor in Tarrant County. Service is slated to begin in 2018 and projections estimate there will be 14,675 daily passenger trips by 2035.[39] Plans for TEX Rail indicate the service will operate 30 minute headways during peak hours and a train ride along the 27 mile corridor will take approximately 55 minutes.

In 2012, The T received FRA approval to operate DMUs on TEX Rail and in June 2015 signed a \$106.7 million[40] contract with Stadler Bussnang AG (Stadler) to build the system's DMU vehicles. Stadler will build eight Flirt3 models for TEX Rail and will meet Buy America manufacturing requirements. These DMU cars are not FRA compliant.

Figure 15: 2012 TEX Rail DMU Conceptual Model

Fort Worth & Western Railroad (FWWR) and Union Pacific Railroad (UP) operate freight over most of the corridor. It is anticipated that freight service would be limited on shared tracks to outside of peak hours. A temporal separation from the FRA will be required to accommodate the freight traffic in Fort Worth additional double tracking was added on the southwest segment of the track and between Tower 60 and Hodge Yard. Through the Purina Mill area, Tex Rail

[39] http://www.texrail.com/FAQs.aspx#cost

[40] http://www.the-t.com/About/NewsNotices/tabid/98/articleType/ArticleView/articleId/462/The-T-and-Stadler-Sign-Contract-for-TEX-Rail-Vehicles-in-Fort-Worth.aspx

operations were separated from UP[41]. Along the corridor, the City of Grapevine runs the Grapevine Vintage Railroad, a tourist excursion on the weekends from Grapevine Main St station to the Fort Worth Stockyards.

Total System Cost

Estimates for the TEX Rail project indicate it will cost approximately $810 million to complete and is being funded through a variety of sources including a local sales tax from member cities and the Federal Transit Administrations New Starts Funding program (Figure 16). Capital improvements include trackwork, signal updates, the installation of communications and positive train control, and stations. The track must be upgraded to Class IV standards and new sidings must be built[42].

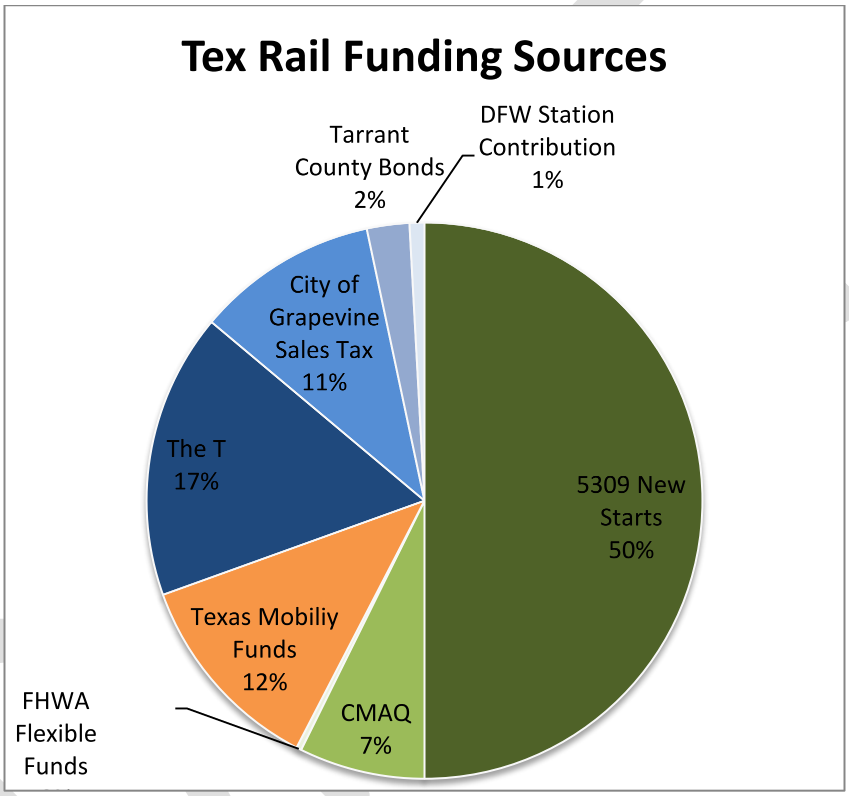


Figure 16: Tex Rail Funding Sources

Annual Operating Costs

The FTA estimates the TEX Rail will cost approximately $10.5 million[43] to operate in its opening year.

Annual Maintenance Costs

The T has not yet projected the TEX Rail's annual maintenance costs.

[41]http://www.texrail.com/Portals/0/Documents/Environmental%20Assessment/TEXRail_EA_Chapter04_TransportationSystems.pdf
[42]http://www.texrail.com/Portals/0/Documents/TEX%20Rail%20Final%20Design%20Services%20Pre-Qualifications%20Meeting%2021MAY2014%20FINAL.pdf
[43] http://www.fta.dot.gov/documents/TX_Ft_Worth_TEX_Rail_Profile_FY15.pdf

History/Background

The TEX Rail project is a result of an alternatives analysis The T completed for the corridor in 2006 in which the study identified commuter rail as the most preferred alternative. Originally this project intended on using locomotive hauled coaches, but later approved DMUs because of their lower operating costs, better funding opportunities, and quieter technology which reduced the need for sound walls along the corridor. As of June 2015, the TEX Rail project has now entered into the engineering phase which is the last phase before construction will begin. Construction is slated to begin early 2016 with operations starting late 2018.

Relevant Lessons Learned

- DMUs are a more cost efficient option and can share tracks with the existing rail line.
- DMUs are quieter and reduce the need for sound walls

4.2.7 Sprinter – North County Transit District - San Diego County, CA

System Characteristics:

North County Transit District (NCTD) operates a DMU Light Rail Line along a 22 mile corridor, with 15 stations, from Oceanside to Escondido, CA. NCTD purchased this corridor jointly with Metropolitan Transit System (MTS) in 1992 as part of a larger railroad corridor purchase from Burlington Northern Santa Fe (BNSF). The cost of the 22 mile corridor was $24 million. BNSF have a rail freight easement that allows freight operations to run in the late night and early morning along the corridor. The Sprinter operates on a single line that is double tracked in various segments.

Figure 17: NCTD DMU "Sprinter"

NCTD purchased 12 VT642 Desiro Articulated DMU units from Siemens in 2007 at a cost of $4.3 million each. The units were manufactured with modifications to help meet the California Public Utilities Commission (CPUC) requirements; these modifications included inboard brakes, additional air conditioning units, and deployable thresholds to close the gap between the platform and floorboard of the car. The units were manufactured in Germany and are non-compliant with the FRA. The Sprinter's vehicles can accommodate 136 seated and 90 standing passengers and can reach a maximum speed of 50mph.

NCTD contracts its operations and maintenance out to Transdev, formerly known as Veolia. The Sprinter operates between 4:00 AM and as late as midnight on 30-minute frequencies during weekday peak. When the Sprinter is not in operation, all units are removed from the main line and the line is then opened for heavy freight operations. Freight operations run three nights a week. Should a freight vehicle breakdown on the line overnight, the Sprinter would not be able to operate until the main line is cleared. Scheduled travel time for the entire route is 56 minutes. The NCTD reports an average weekday ridership of 8,300.

Total System Cost

The Sprinter project was estimated to cost $352 million but due to delays and overruns ended up costing $477 million[44] and began construction in 2004 and was completed in 2008. The cost encompasses the entire project including, but not limited to, the design, land and right-of-way acquisitions, construction, stations, fare collection technology, vehicles, and new tracks. The Federal Transit Administration approved $152 million in funds for the project in 2003.[45]

Annual Operating Costs

According to the National Transit Database (NTD), the Sprinter cost $14,725,284 to operate in FY 2013; this equates to a cost per revenue mile of $27.75 and cost per revenue hour of $609.01. 29% of the cost is for administration, 37% for operations and the remaining is for maintenance. Transdev (Veolia) currently holds the operations and maintenance contract for the Sprinter, although the vehicle maintenance is subcontracted out to Bombardier. Veolia was awarded the original operations and maintenance contract in April 2006 for $27.1 million[46]. In 2011, NCTD approved a two-year contract extension with Veolia with an additional 18-month extension to June 2016.[47]

Annual Maintenance Costs

In FY 2013 NCTD spent $2.1 million on vehicle maintenance and $2.8 on non-vehicle maintenance. The cost for the vehicle maintenance is for the contract with Veolia. The non-vehicle maintenance contract includes insurance, track maintenance, and station maintenance.

In March 2014, the Sprinter service was shut down for two and half months due to brake problems. During this period, the NCTD continued to pay $3.2 million for operations and maintenance on top of an additional $1.3 million for replacement buses to transport passengers. The length of this shutdown was due in part to the one-off design of the Sprinters vehicles. Replacement parts for the custom built vehicle were not readily available and were procured from overseas which further delayed resuming service. As a result of this incident, NCTD executed a supplemental agreement with Veolia that instated new procedures to help identify maintenance risks on the Sprinter vehicles in order to prevent another shutdown.

History/Background

Prior to implementing the Sprinter, passenger service on the corridor had been discontinued for over 50 years since 1946. Although this service had been discussed for many years, the project

[44] Info from Tom Letterman
[45] http://www.lightrailnow.org/news/n_sd_2008-05a.htm
[46] http://www.utsandiego.com/uniontrib/20060421/news_1mi21nctd.html
[47] http://www.transdevna.com/Veolia/media/VeoliaPress/Veolia_Awarded_Sprinter_Contract_Extension.pdf?ext=.pdf

gained support once NCTD purchased the corridor in 1992. DMUs were selected because it was a more cost efficient option. At the time, NCTD received estimates that infrastructure for implementing an electrical service would have cost an additional $100 million. The FRA allowed NCTD to obtain waivers showing the system was being regulated under a state safety system (CPUC) and equivalent safety was provided.

Relevant Lessons Learned

Lessons learned include the following:

- Purchasing a one-off model can create repair and maintenance complications and could temporarily halt service.
- Temporal separation could halt service if a freight vehicle were to breakdown on the line and could not be removed before the Sprinter service normally begins.
- Thorough maintenance inspections can prevent unnecessary shutdowns.

4.2.8 Chugach Forest Whistle Stop Service – Alaska Railroad

System Characteristics:

Alaska Railroad Corporation (ARRC), in partnership with the United States Forest Service (USFS), operates a DMU rail service along existing railroad tracks between Portage and Moose Pass, Alaska. The corridor is approximately 25 miles long. Five stations have been planned for development along the existing tracks, although only two have been completed as of March 2015. Construction at the first stop, Spencer Glacier Whistle Stop was completed in 2007.

Figure 18: DMU "Chugach Explorer"

The DMU vehicle was designed by Colorado Railcar Manufacturing and put into service in May 2009. The vehicle is bi-level, FRA compliant, and can accommodate 90 seated passengers on the top level and 20 seated passengers[48] on the bottom level. Known as the Chugach Explorer, the DMU vehicle is designed to reach a speed of 110 mph[49], although ARRC enforces a maximum speed of 60 mph on the rail line. The Chugach Explorer shares rail tracks with the existing Alaska Railroad locomotives. Although the vehicle can operate on its own, it is

[48] http://www.fs.usda.gov/detail/chugach/home/?cid=STELPRDB5080474
[49] http://www.fs.usda.gov/detail/chugach/home/?cid=STELPRDB5080474

currently used on another passenger train, the Glacier Discovery Train. Initial plans from 2005 propose the service will make four daily round trips; each round trip will be roughly four hours long.

Total System Cost

The total cost for the Whistle Stop project is not definitive as phases of the project are only completed as funding becomes available. The initial cost of the five planned Whistle Stop stations was estimated at over $14 million. Funding for these stations has been supplemented by various federal grant programs such as the American Recovery and Reinvestment Act. To date, $11 million has been invested in the project for infrastructure development and the procurement of the DMU vehicle. The first DMU vehicle was purchased for $5.35 million and was mostly funded by a $4.7 million grant from the Federal Transit Administration. ARRC contributed an additional $648,000[50] to the purchase and the vehicle was put into service on the corridor in 2009.

Annual Operating Costs

NTD data for annual operating costs is not currently available for the DMU service. ARRC reports costs for all of their services in one category, and therefore it is not possible to discern what costs are associated with the DMU only.

Annual Maintenance Costs

NTD data for annual maintenance costs is not currently available for the DMU service. ARRC reports costs for all of their services in one category, and therefore it is not possible to discern what costs are associated with the DMU only.

History/Background

In 2003, ARRC and the USFS joined forces to develop the Whistle Stop rail service. The goal of this service is to provide access to planned recreational areas in the Chugach National Forest while protecting the park’s sensitive environment and resources. DMU vehicles were selected for this service as they would have the least impact on the environment compared to other locomotive options. Although the service only operates on one DMU vehicle currently, it is planned to add additional vehicles in the future. Project plans detail four phases of construction along the corridor for the five stations and recreation development. As of March 2015, only two stations of the project have been completed; the remaining phases will be completed as funding becomes available.

Relevant Lessons Learned

- Relatively new service, construction of stations along the corridor is not complete.
- Service is geared more towards tourism and recreational market.
- DMUs are flexible and can operate independently or as part of another train depending on what the service needs are.
- Phasing of the project makes it easier to fund and build.

[50] https://www.alaskarailroad.com/Portals/6/pdf/projects/2015_03_26_ChugachWhistleStop_FS_PROJ.pdf

4.2.9 WES – TriMet - Beaverton – Wilsonville, OR

System Characteristics

TriMet operates the WES line, a 14.7 mile commuter rail corridor from Beaverton to Wilsonville, OR, stopping at 5 stations. The track consists of a series of single track, passing sidings and occasional double tracking. The equipment is FRA compliant and operates alongside Genesee & Wyoming Railroad (P&W). P&W runs 6-7 freight trains a day.

Figure 19: WES Colorado Railcar

Figure 20: WES Budd RDC DMU

The new service uses a mixed fleet of three Colorado Railcars with power, one trail and two old Budd RDCs., all are FRA compliant. The Colorado Railcars were built by Colorado Railcar LLC (which subsequently went out of business and the intellectual rights were purchased by US Railcar). Each RDC car can hold up to 76 passengers seated plus 96 standing and can reach speeds up to 85 MPH. The Colorado Railcar DMU can hold up to 70 seated and 97 standing and can reach speeds up to 90 MPH. In order to meet ADA, FTA, and Oregon DOT standards for boarding and still maintain freight activity a gauntlet track was added in 2006. Prior to this TriMet had to use platform extensions.

Operations are contracted out to Portland and Western Railroad. Service is operated during the peak hours only from 5:20AM- 10AM and 3:30PM-8PM, there is no weekend service. Since the line is 70% single and 30% double tracked, service is limited to 30 minute peak service. Scheduled travel time for the entire route is 27 minutes[51] and the daily average ridership is slightly over 1,800[52]. On time performance data for the route is 90%[53]. Ridership is projected to grow and in 2016 will require the use of all DMU units. TriMet explored procuring new vehicles but the market for complaint vehicles is very small in the US. Since their vehicle specifications re similar to that of SMART they were named as an option on the SMART contract with Nippon

[51] http://trimet.org/wes/
[52] http://www.apta.com/resources/statistics/Documents/Ridership/2014-q4-ridership-APTA.pdf
[53] Interview with Darren Morris of TriMet

Sharyo[54]. Further research has shown this is not a viable option though as the cost and timeline do not meet TriMets needs.[55] TriMets budget was $8.5M and the units were needed by 2016, Nippon could not get a unit built until 2020 and at double the cost.

Total System Cost

Construction began in 2007 to update the railway to accommodate train speeds of 60 MPH and freight trains of 40 MPH. Centralized Traffic control signaling, automatic train stop, new passing sidings, and stations were also constructed. The total project cost $161.2 million and ran significantly over budget (**Error! Reference source not found.**).[56] Funding for the project came from local state and federal sources (**Error! Reference source not found.**). The $161.2 includes the purchase of the Colorado Railcars but not the Budd RDC. The 4 Colorado Railcars cost $26 million in total. The two Budd RDCs were purchased and refurbished for $225,000 each, a fraction of the price of the Colorado Railcars.

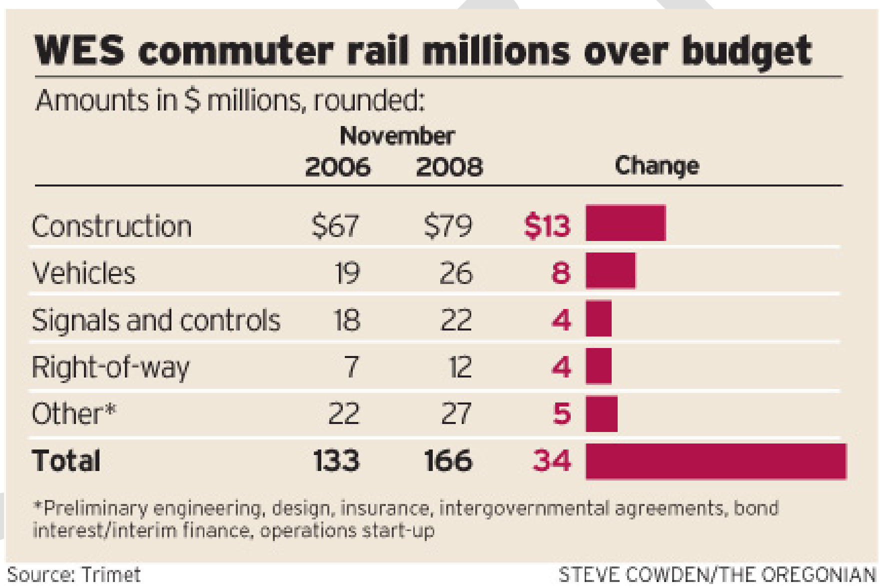


Figure 21: WES Capital Cost

[54] http://trimet.org/pdfs/meetings/board/2014-4-9/wes-dmu-presentation-4-9-14.pdf
[55] Interview with Darren Morris of TriMet
[56] http://trimet.org/pdfs/history/railfactsheet-wes.pdf

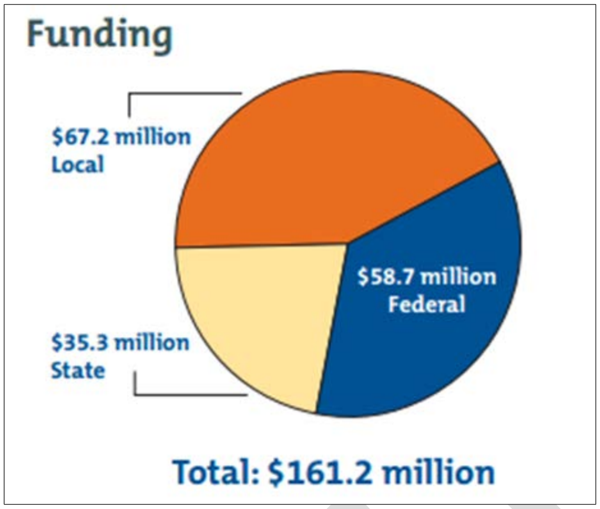


Figure 22: WES Funding Sources

Annual Operating Costs

National Transit Database (NTD) reports show that the cost to operate the line was $7,036,033 for FY 2013, this equates to a cost per revenue mile of $43.41 and cost per revenue hour of $942. General administration accounted for 28% of the cost, operations 44% and the remaining was maintenance. Through the shared use agreement with Genesee & Wyoming (P&W), TriMet must pay $200K a month for P&W's wages and benefits for 1 train master, 2 switch and signal maintainers, dispatchers and overhead. This does not include TriMet employees.

Annual Maintenance Costs

NTD data shows that $1,420,211 was spent on vehicle maintenance and $549,902 on non-vehicle maintenance. Non-vehicle maintenance includes such things as facility, station and track maintenance, fare collection equipment and counting, and communication systems. TriMet has experienced maintenance issues with both the Budd RDCs and Colorado Railcars. Many of the issues stem from the Budd RDCs and their age. There have been a few instances where one of the engines stops working while in service and if the units had not had two engines it could have halted or slowed down service along the line. Shortly after TriMET took ownership of the Colorado Railcars there were issues. Within days of the service opening, one of the units caught fire due to faulty wire installation by the manufacturer. A bundle of wires were hung in the wrong place inside the wall of a railcar and unknowingly had screws drilled into it to hold up the baseboard heaters[57].

History/Background

In 1996, planning began to study the feasibility of passenger rail on the 100-year-old rail corridor. In 2002, the project was taken over by TriMet from the County. Construction began in 2007 to update the railway to accommodate train speeds of 60 MPH and freight trains of 40 MPH. The tracks were upgraded using specialized equipment called the P811 which replaced 14 miles of track in 30 days[58]. Track upgrades and stations were complete by 2008 using the P8111

[57] http://www.oregonlive.com/news/index.ssf/2009/02/wes_service_off_track_for_seve.html
[58] http://trimet.org/pdfs/history/railfactsheet-wes.pdf

track renewal system[59] but due to delays in the Colorado Railcar DMUs service did not begin until 2009. In 2009, TriMet purchased and refurbished two 1952 Budd RDCs from Alaska Railroad (Alaska Railroad had purchased them from the New York New Haven and Hartford Railroad who were the original owners of the units) after a failed attempt to piggyback on the SMART Nippon procurement.

The decision to use DMUs as opposed to alternative rail modes was because the commuter rail was operating along an existing freight line and needed to be FRA compliant, temporal separation was not an option. DMUs were chosen over LHC for their bidirectional capacity and shorter station platform requirements.

Relevant Lessons Learned

Lessons learned include the following:

- Larger manufacturers won't accommodate small orders and piggybacking off another's contract may significantly increase the cost per unit and delivery time.
- Make sure each unit has two engines.

4.2.10 SMART – Larkspur, CA

System Characteristics:

Sonoma-Marin Area Rail Transit (SMART) is a planned passenger rail service covering a 70 mile corridor between Larkspur and Cloverdale, CA. This corridor has not seen passenger rail since 1958. The project consists of two phases; phase one is scheduled to be completed in 2016 and passenger service will begin in late 2016. The passenger rail will service 14 stations with level boarding platforms. The DMU vehicles, which are FRA and Buy America compliant, will share rail tracks with Northwest Pacific Railroad. SMART service is expected to carry up to 6,000 passengers daily.

[59] The P8111 machine passes over the track removing old ties, leveling and compacting ballast and laying new rails all in one pass.

Figure 23: SMART DMU by Nippon Sharyo

SMART procured 14 DMU cars (seven 2-car trains) from Nippon Sharyo, who established a plant in Rochelle, IL[60]. The pilot set has undergone testing at the Transportation Test Center in Pueblo, CO and were delivered to SMART in the Spring of 2015. The final set of cars were delivered in Summer 2015 with testing to being in November. These cars meet the “Tier 4” EPA requirement and each train set (consisting of two DMU cars) accommodate 158 seated passengers, 160 standing passengers and 24 bicycles. To meet Buy America requirements the vehicles were manufactured in Rochelle, IL. Vehicles can reach a top speed of 79 mph but with station stops will average 40 mph. Service will operate on 30 minute headways, and service on phase 1 from San Rafael to Sonoma County Airport (43 miles) will take roughly 67 minutes.

This project includes replacing the 60-100-year-old track with new rail, ballast, ties, and switches, adding a communications system along the entire corridor complete with a data center and central control room as well as grade crossing and signals upgrades. As the train goes over the rail it picks up messages sent by the communications system where it is decoded and sent to the train engineers. By the end of 2015, SMART will begin testing this integrated communication system with DMUs. Positive train control was installed. This prevents dispatchers from sending trains on unsafe movements. The track design also uses gauntlet tracks so that the freight trains can pass away from the platforms.

Total System Cost

The estimated cost of Phase 1, which covers 43 miles of the 70 mile corridor between Downtown San Rafael to Sonoma County Airport, is $428 million.[61] Of this cost, $347.8 million will be spent on construction contracts and $80.1 million will be funding for capital project

[60] http://www2.sonomamarintrain.org/userfiles/Board_Workshop_DMU_and_Systems_%28Lisa_Cobb%29_2-11-15.pdf
[61] http://main.sonomamarintrain.org/wp-content/uploads/2015/02/Project-Overview-Feb-2015-English.pdf

management.[62] SMART entered into a contract with Nippon Sharyo for 12 DMU vehicles with the option for additional ones. The unit price for the first 12 was $3.3M per car and each additional afterwards was $2.9. The total contract for the 14 vehicles was $45.7M[63]. Over the past five years, SMART has aggressively pursued grant opportunities at the regional, state and federal levels to fund construction costs. They have successfully secured $122.6 in grants (Table 2). The reaming funding is from bond proceeds ($180 million) and sales and local taxes (125.3 million)[64].

Table 2. SMART grant funding sources

Regional, State, and Federal Grants Received to Date	
Sonoma County Transportation Authority Measure M	$16.2 million
Metropolitan Transportation Authority Bridge Tolls (RM2)	$48.4 million
State Funds (SLPP/Proposition 116)	$37.3 million
Sonoma County Transportation Authority other funds	$6.6 million
Federal Funds	$12.8 million
Miscellaneous	$1.3 million
Total	$122.6 million

Completion of future project elements is estimated to cost an additional $225 million. Funding for the SMART project is a mix of state and federal money, matching funds from a local sales tax and NCRA, and various other grant programs.

Annual Operating Costs

SMART has projected an annual operating cost of approximately $17.8 million (Table 3); this figure is likely to change as Phase 1 of the project is completed and SMART begins service in late 2016. Labor includes fringe benefits for 77 positions (conductors, maintenance, engineers, controllers, administration). Since many of the operating costs are fixed costs, it is projected that the Larkspur extension in phase 2 will only add $35,000 annually. Operating funds will come to the Measure Q sales tax, farebox revenue, state transit assistance, and joint development and lease opportunities, FTA 5307 formula funds and the State's Cap and Trade revenues for rail operators.

Table 3. Annual operating Costs

Annual Operating Costs (beginning Fiscal Year 2016-17)	
Labor	$10,019,505
Non-labor (services/supplies)	5,811,405
Insurance	2,000,000
Total	$17,830,910

62 http://main.sonomamarintrain.org/wp-content/uploads/2014/12/SMART-2014-StrategicPlan-Final.pdf
63 http://www2.sonomamarintrain.org/userfiles/file/Passenger%20Vehicle%20PPT%20v9%20092111.pdf
64 http://main.sonomamarintrain.org/wp-content/uploads/2014/12/SMART-2014-StrategicPlan-Final.pdf

Annual Maintenance Costs

Projections for annual maintenance costs are not yet available. SMART's planned Operations and Maintenance Facility is located at Airport Blvd. and is currently testing equipment for use on the new rail line.

History/Background

Funding for the SMART project was approved by California voters as part of Measure Q in 2008. Measure Q, which was passed with nearly 70% approval, is a ¼-cent sales tax that will fund the construction, operation, and maintenance of the SMART project over the next 20 years. The measure went into effect in April of 2009 and is projected to generate $756.6 million over the 20 years. Once completed, the SMART service is expected to relieve congestion on Highway 101 by taking off 1.4 million[65] vehicle trips annually. Design of the system was completed in 2011 and construction started shortly after.

The decision to use DMU over other technologies was due to the presence of freight traffic, and an alternative vehicle analysis which showed that DMUS were more environmentally friendly and the most cost effective. There were also platform length restraints that limited train length to less than 290'.

Relevant Lessons Learned

- Strong support from the local community.
- A local sales tax, such as Measure Q, can help fund the project.
- Actively pursue all local, state and federal grant opportunities.

4.2.11 Tri-Rail Commuter Line – SFRTA – Miami, FL

System Characteristics:

South Florida Regional Transportation Authority (SFRTA) operates Tri-Rail, a commuter rail line covering a 70.9 mile corridor and connecting the cities of Miami, Fort Lauderdale, and West Palm Beach. Tri-Rail operates DMU vehicles and services 18 stations along the corridor on shared rail tracks with other locomotives.

SFRTA began the procurement process for a DMU vehicle from Colorado Railcar in 2003; an additional three DMU cars and two trailer cars were added to the system later. SFRTA operates two DMU trains; these trains have a DMU vehicle at each end with an unpowered trailer car in the middle. The double deck DMU, the first car in the picture below, is 89 feet long and has 188[66] passenger seats. Service on the Tri-Rail operates at 20 to 30 minute headways during weekday peak and average daily ridership on the 14,800. On-time performance for FY14 was 86.2%[67].

[65] http://www2.sonomamarintrain.org/index.php/what_is_smart/
[66] http://www.alaskarails.org/fp/passenger/751/dmu-brochure-2005.pdf
[67] http://www.sfrta.fl.gov/docs/planning/TDP/SFRTA-TDP-Annual-update-FY-2015-2024-Final-draft.pdf

Figure 24: Tri-Rail DMU Train

The four DMU vehicles most recently added to the system are only in service temporarily. These units were originally purchased for SunRail, a new commuter rail line in Central Florida, with federal grant money. At the time, SunRail was unsuccessful in getting the necessary approvals to run DMUs on their system, so the vehicles have been essentially "loaned" to Tri-Rail until SunRail is ready to put them into service.

Total System Cost

SFRTA purchased 4 double decker DMU units plus two double-decker trailers in order to create 2 full train sets. The DMU units were reported to cost $4.1 million each and the trailers $2.8 for a total of $22 million[68].

Annual Operating Costs

According to the NTD, the Tri-Rail cost $58,051,892 to run in FY2013; this equates to roughly $18.34 per vehicle revenue mile and $566.35 per vehicle revenue hour. SFRTA currently holds an operation contract with Veolia Transportation. During FY2013, the budget for this contract was $11,356,868.[69] The proposed budget for this contract increased 3.9% for FY2014 to $11,801,046.

[68] From the 2011 APTA vehicle database
[69] http://www.sfrta.fl.gov/docs/Overview/SFRTA-Operating-Budget-FY-2014-2015.pdf

Annual Maintenance Costs

SFRTA contracts its maintenance to Bombardier Mass Transit for its rolling stock and facility equipment. The budget for this contract during FY2013 was for $18,406,716; the proposed budget for FY2014 increased 5.88% to $19,489,863. Meridian Management Corporation holds a contract for station maintenance with SFRTA budgeting $2,393,584 for this contract in FY2013. ROW maintenance costs $15,675,000.

History/Background

Tri-Rail was established in 1989 to provide commuter rail service along an existing 67 mile corridor[70] between Palm Beach County and Miami-Dade County. Since then, the service has expanded to new regions. The introduction of the DMU vehicle on the Tri-Rail system began in 2003 when Colorado Railcar tested their DMU car on the rail line. In 2004, the Florida Department of Transportation received a grant to fund a pilot project to test DMU vehicles on passenger rail service and selected SFRTA for the demonstration project.[71] Since then, acquisition of DMU vehicles has been strongly supported by Congressman John Mica, Chair of the House of Representative's Transportation and Infrastructure Committee.

Relevant Lessons Learned

- Strong political support aided in procuring DMU vehicles for the service.
- System has not yet gone into service; GO Transit in Toronto purchased 18 Nippon Sharyo DMUs at the same time as SMART. GO Transit began service in June 2015

4.2.12 Metrolinx – Union Pearson Express (UP Express), Toronto, Canada

System Characteristics:

Metrolinx, an agency of the Government of Ontario, under the Metrolinx Act, 2006, was created to improve the coordination and integration of all modes of transportation in the Greater Toronto and Hamilton Area.

[70] http://www.sfrta.fl.gov/docs/planning/TDP/SFRTA-TDP-Annual-update-FY-2015-2024-Final-draft.pdf
[71] http://www.dot.state.fl.us/rail/Publications/Plans/2004/PsgrComponentFull.pdf

Metrolinx was asked to build, own and operate the Union Pearson Express (UP Express) in July 2010. UP Express operates between Union Station and Toronto Pearson International airport in 25 minutes, with trains departing every 15 mintues, 19 ½ hours a day. Operating along GO Transit's Kitchener line it also makes stops at Bloor and Weston Stations. The UP Express operates alongside GO Transit commuter trains, VIA Rail passenger trains, and CN Rail freight train.

Metrolinx purchased 18 Nippon Sharyo DMU vehicles. These single deck Tier 4 compliant DMU vehicles are 85 feet in length and can operate at 90 mph.[72] They are the same FRA compliant equipment ordered by Sonoma Marin, CA, scheduled to be in service by the end of 2016.

Total System Cost

On March 1, 2011, Metrolinx announced a purchase agreement with Nippon Sharyo for 12 DMU vehicles (six 2 vehicle trains) for a cost of $53 million CAD.[73] Later the order was increased by 6 more DMU for a total fleet of 18 DMU vehicles.

Annual Operating Costs

The total annual operating cost for UP Express was $18,993,000 CAD.[74] This cost includes Operations, Mechanical, Customer Service/Ticket sales, Marketing and the UP Express management team. The Operations and Mechanical, services contracted to Bombardier through GO Transit. The Customer Service is contracted to Bombardier directly with UP Express.

History/Background

The idea of linking downtown Toronto Union Station to Pearson International Airport was not a new one. The Air Rail Link as it was known, became the focus of several reports starting in 1989. In April 2001, Transport Canada issued a request for proposal for an airport rail link. The successful proponent was SNC-Lavalin who were awarded the finance, design, construct, operate and maintain contract on November 13, 2003. However by 2008 no significant progress had been achieved and in July 2010 the private/public partnership had been canceled. Metrolinx was directed to take over the project and ensure that it was operational by the July 2015 Pan Am/Parapan Am games being held in Toronto.

On June 5, 2015 UP Express entered revenue service.

[72] http://www.nipponsharyousa.com/products.htm

[73] http://www.webcitation.org/5wrZIanHt
[74] http://www.metrolinx.com/en/aboutus/publications/Annual_Report_2014-2015_EN.pdf

Relevant Lesson Learned

- Customers are price sensitive and the original UP Express ticket prices need to be reduced to increase ridership.
- Political commitment was required to ensure that this project was successfully launched.
- Wayfinding signage is critical when launching a new service.
- Educating the public about Tier 4 compliance is critical in building support.
- Supply chain management is critical as DMU parts can have significant lead times due to being produced in Japan.
- While maintenance of DMUs is carried out in the same facility as Metrolinx conventional rail equipment, new maintenance personnel had to be trained for this equipment. Long term plan is to fully integrate training so all Metrolinx maintenance can work on all rail equipment.

Table 4. Summary of DMU Line and Service Characteristics, U.S.

Operator/Location	Service Name and Initiation Date	DMU Route, Track, speeds	# Stations, Ridership	Number, type of cars	Freight Use	Compliance, Other Notes
In Operation						
New Jersey Transit (NJT), NJ	River LINE (March 2004)	• 34.4 miles, Camden to Trenton, NJ, single and double tracked, 55 mph	• 21 stations, • 9,000 weekday riders	• 20 Stadler GTW	• Temporal by Conrail 10 PM to 6 AM	• Not FRA compliant, • temporal separation waiver, • Operated by Southern New Jersey Rail Group
North County Transit District (NCTD), San Diego County, CA	Sprinter (January 2008)	• 22 miles, Oceanside to Escondido, CA, with 8 miles of passing sidings • Top speed – 50 MPH	• 15 stations • 2.4M annual ridership	• 12 vehicles, Siemens (136 seated, 90 standing) • Level boarding, wide doors • Initial fleet 12 vehicles at $52.2 M (2008) ($4.4/car) • Operating costs - $11M/year;	• BNSF operates freight 3 nights/week. • Platforms are raised so freights can run.	• Not FRA compliant, regulated by California Public Utility Commission; NCTD received variance for some deviations from state regulations but was required to improve braking • Operator: Veolia/Bombardier for maintenance
Denton County Transportation Authority, Denton County, TX.	A Train (June 2011) Denton-Carrolton, TX	• 21 miles • Top speed – 50 MPH	• 6 stations • 2,000 daily ridership	• 11 Stadler GTW Cars and 10 BUDD cars	• Dallas Garland and Northeastern Railroad	• NonFRA-compliant vehicles but FRA Waiver granted to operate • Operator: Herzog

Operator/Location	Service Name and Initiation Date	DMU Route, Track, speeds	# Stations, Ridership	Number, type of cars	Freight Use	Compliance, Other Notes
Trinity Railway Express (TRE) Dallas/Fort Worth, TX	TRE	• 34 mile Commuter rail between Forth Worth and Dallas, TX	• 10 stations, 7,300 daily ridership	• 13 BUDD cars	• No fright but a mix of diesel locomotives with passenger cars and DMU used.	• FRA-compliant. DMUs used as spare vehicles • Operator: Herzog
Capital Metro (CapMetro), Austin, TX	Red line (March 2010)	• 32 miles Austin to Leander TX	• 9 stations, • 1,500 passengers per day	• 6 Stadler GTW • 108 passengers seated	• Watco operates 2-3 freight trains a night	• Not FRA compliant, FRA Waiver for temporal separation, • Operator: Herzog
TriMet, Portland, OR	Westside Express Service (WES) Line, February 2009	• 14.7 miles, Beaverton to Wilsonville, OR • Average speed 37 MPH; top speed 60 MPH	• 5 stations, P&R at 4 stations • 512,000 annual ridership	• 4 Colorado Railcar/US Railcar and 2 BUDD • 95 passenger capacity. • Level boarding	• Shares track with Portland & Western	• FRA Compliant, • commuter rail service
Alaska Railroad	Chugach Forest Whistle Stop Service (May 2009)	• 60 MPH	• 5 Stations (only 2 are constructed)	• Colorado Rail Car	• Shares track with other Alaska Railroad locomotives	• FRA compliant
South Florida Regional Transportation Authority (RTA)	Tri-Rail commuter line (2006)	• 70.9 miles	• 18 stations • 14,800 daily ridership	• 4 Colorado Rail Car power units, 4 trailers, $5.01 M	• Shares track with CSX	• DMUs originally purchased for SunRail, used on Tri-Rail until SunRail opens
GO Transit	Union Pearson Express	•	• 4 stations • 2500 daily ridership	• 18 Nippon Sharyo units, compliant with U.S EPA Tier 4 emissions standards	• N/A	• Meets FRA Tier 1 Compliance standards

In Planning or Construction						
Sonoma – Marin Area Rail Transit (SMART)	Phase 1 to open 2016	• 70-mile corridor from Larkspur to Cloverdale, CA. • Phase 1 is San Rafael to Santa Rosa, CA	• 10 stations	• 14 Nippon Sharyo • Level boarding	• Northwest Pacific Railroad	• FRA compliant • Buy America Compliant
Massachusetts Bay Transportation Authority (MBTA), Boston, MA	Fairmount Line	• 9.2 miles from Boston to Readville	• 8 active 1 planned	• Acquiring 30 DMUs	• Will share portion of track with other Commuter rail lines using locomotives	• Funding eliminated, project on-hold
Fort Worth Transportation Authority, Tarrant County, Texas	TEX Rail (planned to open September 2018)	• Downtown Fort Worth to DFW Airport (27 miles)	• 12 stations	• Acquiring 8 Stadler DMUs	• Grapevine Vintage Railroad, FWWR, and UP	• Project under construction

Chapter 5. DMU Applicability to Commuter Rail Operations in Connecticut

5.1 Potential Corridors For DMU Operations

The Waterbury Secondary Line traverses 24.3 miles between Waterbury and Berlin and is the focus of the CCRS study. This line, which is owned by Pan Am (PA), currently operates only rail freight service.

The Waterbury Branch is one of the three branches off of the New Haven Line, which is served by Metro-North Railroad. This branch begins in Bridgeport, travels through to service stops at Stratford, Debry-Shelton, Ansonia, Seymour, Beacon Falls, Naugatuck and lastly in Waterbury. Currently, this corridor operates 15 weekday trains and experiences approximately 1,014 daily passengers.

New Haven-Hartford-Springfield (NHHS) Line operates passenger service at stops beginning in New Haven, Wallingford, Meriden, Berlin, Hartford, Windsor, Windsor Locks and lastly in Springfield, MA. This line is part of Amtrak's Northeast Regional service and consists of six weekday southbound trains and seven weekday northbound trains. Of the 380,986 passengers recorded in FY 2011, 6.2% (23,465) boarded at Berlin Station.

5.2 Stakeholder Input

Implementation of passenger rail service along the CCRS Line would require extensive input from a variety of stakeholders including national agencies, rail operators, governmental agencies and other entities. The following stakeholders have been identified as having a significant role in the implementation of service using DMU vehicles:

The **Federal Railroad Administration** (FRA) would be heavily involved in the logistics of operating passenger service with DMU vehicles. The FRA has enacted many regulations regarding the safety standards of DMUs particularly if the service is to operate in conjunction with freight service. If DMU vehicles selected for service are non-compliant with FRA regulations, coordination with the FRA will require obtaining a waiver to indicate other satisfactory safety procedures are in place.

The **Connecticut Department of Transportation** (CTDOT) would oversee the implementation of passenger service on the CCRS Line.

Pan Am Railroad owns the 24.3 rail line between Waterbury and Berlin, which is known as the Pan Am Southern Line (PAS Line) or Waterbury Secondary. As the owner, PAS would have significant involvement in any infrastructure upgrades or service changes on this line.

Metro-North Railroad (MNR) would be heavily involved in the implementation of passenger service. The use of DMU vehicles would require significant coordination to effectively implement passenger service to match the existing passenger service windows at the Waterbury Station.

Amtrak, similar to MNR's position, would also be a key stakeholder in the implementation of service. Implementing passenger service would require infrastructure upgrades to the line in order to be compatible with DMU vehicles. Coordination of passenger service on the CCRS Line would also require coordination with the existing passenger service operated at Berlin Station by Amtrak.

5.3 DMUs and Positive Train Control

Positive Train Control (PTC) is a safety technology which monitors train movement and if necessary takes over control in the event of human error. PTC was designed specifically to to prevent train-to-train collisions, protect against trains exceeding maximum authorized speeds (overspeed protection), and to protect railroad and contactor work crews through the enforcement of temporary speed restrictions.

PTC allows atrain dispatcher to temporarily impose speed reductions in areas where there are workers on adjacent tracks, or slow down trains at crossings if the grade crossing waring devices have malfunctioned . PTC can operate in either non-signaled "dark" or signalized territory.

Amtrak's **Advanced Civil Speed Enforcement System** (**ACSES**) is a positive train control cab signaling system developed by Alstom and Amtrak. The ACSES PTC system transmits information to the train through transponders installed in the track, coded track circuits and digital radio. It is planned for installation on remaining sections of Amtrak's Northeast Corridor in CT and the Hartford Line. Essential or "vital" communications relay information to the oncoming train's onboard computer which notifies the train engineer of any issue approaching. If the engineer does not respond appropriately, the onboard computer will apply the brakes and safely stop the train.

The second major PTC system technology employed by major freight railroads is one of several variants of Wabtec's communications-based overlay technology that augments existing train control system capabilities, such as using GPS for train positioning in conjunction with an advanced digital radio system to monitor train speed, location, and mechanical health. Similar to ACSES, it is designed to prevent train to train collisions and many types of train accidents. The Wabtec-based systems include an in-cab display screen that warns the train engineer if a problem develops and automatically intercedes to stop the train if the engineer fails to take appropriate action to avoid the problem.

In 2008, congress passed the Rail Safety Improvement Act of 2008, which mandated PTC be installed on most of the tracks in the US by 12/31/2015[75]. Approximately 60,000 miles are subject to the mandate including all Class I railroad that transport hazardous materials and intercity and commuter rail passenger carriers. Since the provisions include all intercity and commuter rail all such services operated using DMU would require PTC. PTC would need to be installed on each DMU vehicle. The mandate was in response to MetroLink Commuter Rail and Union Pacific Freight rail head-on collision which killed 25 people in 2008. Forty-one railroads

[75] https://www.congress.gov/110/plaws/publ432/PLAW-110publ432.pdf

are required to implement PTC and because many passenger and freight railroads share tracks the systems must be interoperable.

Several controversies exist around PTC. The Government Accountability Office (GAO) estimates that it will cost $6-$22 billion nationwide to install PTC, but Congress did not allocate the needed funds. As a result, several systems have had to cut service, reduce preventative repairs, and forgo other planned service expansions of capital improvements to pay for PTC. For example, Metro North had to get a $1 billion loan from the FRA to finance PTC on the Long Island Rail Road and New York portion of Metro-North. There is also skepticism as to the benefits to installing PTC, since according to the US DOT only 35% of accidents during 2000-2009 were a result of human error that could have been corrected with PTC. Many of these accidents were minor and FRA safety standards prevented most loss of life. In the 45 years preceding the 2008 law, there had only been 145 accidents and 296 fatalities which could have been prevented with the installation of PTC[76], this is less than 1% of all railroad associated fatalities.

The Association of American Railroads (AAR) projected that by the end of 2015 only 15% of the freight railroad tracks will be installed with PTC[77]. Congress responded by pushing back the compliance date to 2018, with a case-by-case possible extension to 2020, which is considered more realistic to implement PTC on all required tracks and locomotives. Factors such as the need to find funding, obtaining radio spectrum, the FCC approval process for communication antenna siting, and designing, testing, manufacturing and installing the technology have led to the lengthy implementation process. Railroads have had to develop PTC, as it was not a technology that already existed and it was not until 2010 that the FRA even implemented regulations surrounding PTC. Because the regulations are relatively new the technology is immature, has not undergone extensive testing and there are limited approved manufactures and suppliers, which is causing bottlenecks in obtaining the technology. The installation of PTC is probably the largest, most technically advanced modifications the railroad industry has had to implement. The highly complex computer, track and radio technology must undergo a complex certification process once installed before train operations can begin, per FRA mandates. The issue of interoperability among competing PTC technologies has not yet been finalized, however the industry and FRA are working cooperatively to complete testing and implement fully interoperable PTC systems by Dec 2018.

In Connecticut (CT), the State Department of Transportation (DOT) is funding the installation of ACSES PTC along Metro-North railroad. Along the mainline PTC installation is continuing and the branches are planned for completion by the summer of 2017. CTDOT anticipates the cost to be $142.6 and is working with Amtrak to install ACSES PTC along the New Haven-Hartford-Springfield line. The project will be complete by 2018 when the service is set to begin[78]. Amtrak has already installed ACSES PTC between New Haven and Boston, along the Shoreline East corridor. Currently the CCRS corridor is not subject to the PTC requirement, but the installation of commuter rail (locomotive or DMU) would require it.

[76] Hearing of the Subcommittee on Railroads, Pipelines, and Hazardous Materials 6/24/2015 10 AM
[77] https://www.aar.org/policy/positive-train-control
[78] http://www.ct.gov/dot/cwp/view.asp?A=1373&Q=558278

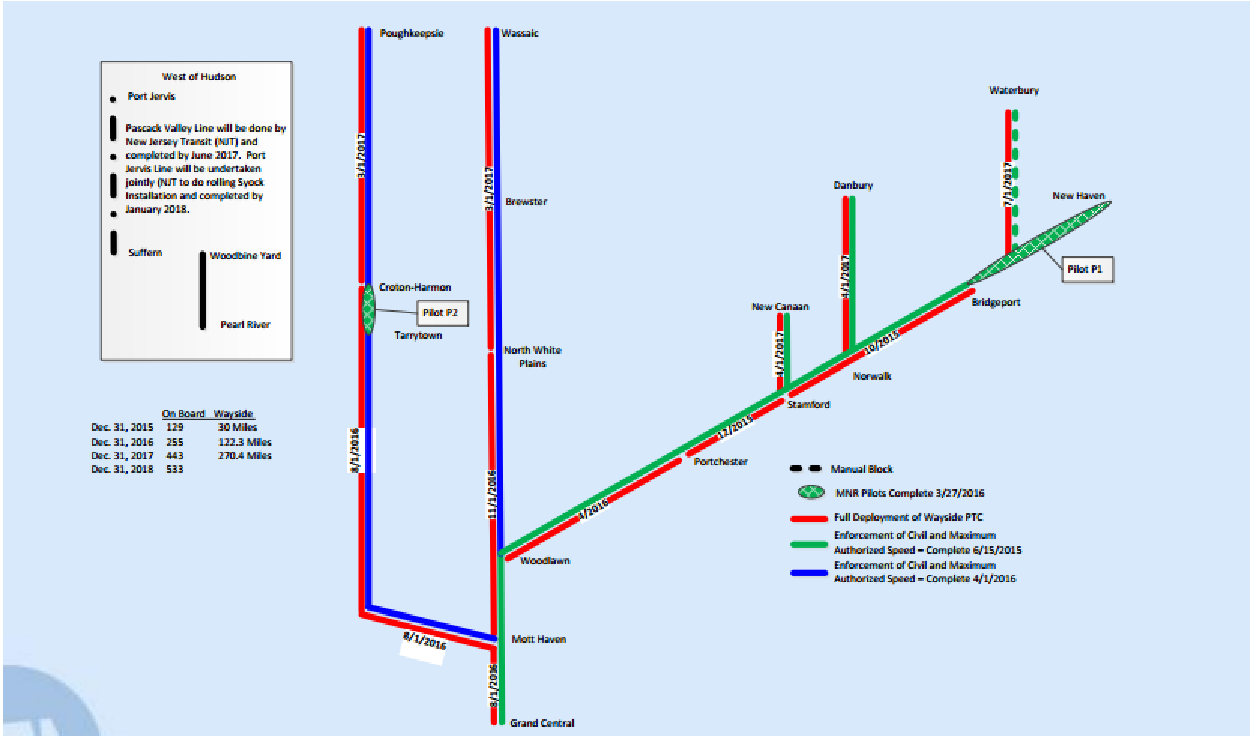


Figure 25: MNR Targeted PTC Implementation

5.4 Operational Requirements of DMUs

There are five alternative scenarios under which DMU could operate. The vehicle requirements were calculated based on the peak period needs. These are more aggressive schedules to account for future growth; it is likely that for the startup longer headways would be established until ridership grows. The first two alternatives are 30 minute frequency in the peak and 60 minutes in the off peak with one being through trains requiring no transfer in Waterbury[79] and the other operating just along the CCRS corridor which would require transfers. The next set of alternatives is similar to Alternative 1 and 2 except the headway would be a consistent 90 minutes throughout the day. The fifth scenario would be to extend the Waterbury branch as far as Bristol and operate with 30 minute headways in the peak and 60 off-peak. The startup scenario would be similar to Alternative 1 (30 minute peak service with a transfer in Waterbury) but there would be 2 hour service in the off-peak instead of 60 minutes. Since the peak headway would remain the same, the number of vehicles needed to operate during the peak would be the same as it is just the off-peak (which requires fewer vehicles than the peak).

Assumptions had to be made regarding operating parameters, they were as follows:

- The average operating speed for DMUs is 40 MPH.
- The one way travel time between Waterbury and Berlin would be 44 minutes. This is based on preliminary schedules and average operating speeds.
- The southbound travel time from Waterbury to the Devon transfer point is 53 minutes, northbound is 55.

[79] The options which are for a one seat ride and do not require a transfer in Waterbury would require significant upgrades to the Waterbury Branch Line in order to accommodate multiple trains. The line is currently signalized and single tracked which limits the number of trains that can be on the corridor to one set.

- From Waterbury to Bristol is 23 minutes.
- There must be a minimum of 30 minutes of layover time on both ends.
- The average DMU can hold 90 passengers seated per cab and units come in a 2 cab set.
- During the peak hours, half of the through train trips would require 2 DMU sets (4 cab cars total).
- During the peak hours, trips which would require a transfer in Waterbury would require 1 DMU cab set.
- The spare vehicles include a protect set, maintenance set, and spares. The number of spare vehicles was determined based on the average spare ratio for existing systems which operate DMUs and do not supplement the service with locomotives and coaches. The average spare ratio was 60%.
- When calculating the spare vehicles required all numbers were round up to the nearest whole.

Table 5. Capital Requirements for DMU

Alternative	Peak Vehicles	Spare Vehicles	Total Vehicles
1) 30/60 Transfer	5	3	8
2) 30/60 Through	13	8	21
3) 90 Through	5	3	8
4) 90 Transfer	2	2	4
5) 30/60 Through to Bristol Only	11	7	18

A cost analysis was done to look at operating costs for DMU service. In the US, there are currently 4 DMUs in operation that are FRA-compliant, with more expected at the end of 2016. The average cost per hour was $580 and ranged from $18.34 to 43.41/mile. This was then compared to the other modes under consideration. Table 5 shows that Commuter rail using traditional locomotive-hauled equipment and cab cars is comparable in cost to DMUs which are FRA compliant.

Table 6. Operating costs for FRA Compliant DMUs

State	Provider	Cost per hour	Cost per mile
TX	Denton County Transportation Authority	$508	$18.93
TX	Dallas Area Rapid Transit	$587	$25.37
OR	TriMet	$942	$43.41
FL	South Florida Regional Transportation Authority	$566	$18.34

Table 7. Average Operating Cost by mode

	Average $/ rev hour
DMU compliant	$580
DMU non-compliant	$725
Commuter Rail	$523
Light Rail	$257
BRT	$154

For all Alternatives it is assumed that service would operate based on the current Waterbury Branch hours (5:46 AM – 12:46 AM) and that the peak periods would be 5 AM to 9 AM and 4 PM to 8 PM. Table 8 below lists the number of trains needed in the peak and off-peak by alternative. To calculate the annual cost to operate service the number of vehicles by period was multiplied by the number of hours in the period. These values were then added together and multiplied by the average operating cost per revenue for DMU compliant equipment. This gives the daily (weekday) operating cost. The weekend daily operating cost was assumed to be 1/3 of the weekday cost since service would be reduced on the weekends.

Table 8. Vehicle Requirements by Period

Alternative	Peak Vehicles	Off-Peak Vehicles
1) 30/60 Transfer	5	3
2) 30/60 Through	13	5
3) 90 Through	5	5
4) 90 Transfer	2	2
5) 30/60 Through to Bristol Only	11	4
6) Start up 30/120 Transfer	5	2

The least expensive alternative would be to have 90 minute service with transfers in Waterbury. It is the least expensive because it is not a one-seat ride, there are fewer vehicles in service thus fewer revenue hours, and the headway is longer. Table 9 outlines the operating cost by alternative. The alternatives which do not have transfers include the cost of operating on the Waterbury branch.

Table 9. Annual Operating Cost by Alternative for DMU

Alternative	Annual Cost (millions)
1) 30/60 Transfer	$13.2
2) 30/60 Through	$28.3
3) 90 Through	$17.6
4) 90 Transfer	$7.0
5) 30/60 Through to Bristol Only	$23.4
6) Start up 30/120 Transfer	$11.0

5.5 Compatibility with Existing Freight Operations

A key component in the implementation of passenger rail service using DMU vehicles surrounds the logistics of operations depending on whether the DMU vehicles are compliant or non-compliant with FRA regulations. As discussed earlier, stringent FRA regulations require DMU vehicles to be in compliance if they are to operate on shared tracks with freight service. If non-compliant DMU vehicles are used, waivers must be obtained and the service may only run on temporal separation, with strict railroad operating rules in effect

While there are existing Pan Am freight operations in Connecticut on the CCRS Line, trains only operate several times a week. However, the freight market analysis indicates there is potential for additional growth along this line in the coming years. Commodities moved by rail into Connecticut include chemicals, pulp and paper, lumber and wood, and iron and steel; commodities moving out the state include waste, scrap, stone, gravel, and sand. Opportunities to expand business along the line could significantly improve if the line offered more consistent and timely service. Currently, the CCRS Line receives roughly 1,300 carloads annually; should new business opportunities on the line come to fruition, rail between Waterbury and Berlin could receive an additional 1,500 to 1,800 carloads each year, effectively doubling business. Expanded business and additional carloads is an important factor in determining compatibility with DMU service. Should this growth take place, freight operations would increase and would impact passenger service, particularly if temporal separation is required.

Passenger rail service is not currently operated on the CCRS Line, however, Metro-North Railroad passenger service terminates in Waterbury and Amtrak provides passenger rail service along the New Haven-Hartford-Springfield Line which stops in Berlin. The introduction of passenger rail service on the CCRS Line connecting to the Waterbury and Berlin stations would require significant infrastructure upgrades including, but not limited to, signalization, Positive Train Control (PTC), grade crossing warning device improvements, installation of passing sidings, tunnel repairs, and track alignments in places to meet platform configurations. These expected return on investment in terms of economic development needs to be further evaluated.

Another requirement to implement passenger rail service using DMU vehicles on the line would be scheduling service to meet the Metro-North and Amtrak passenger schedules. This will be particularly important to coordinate if increased freight operations are required to meet customer demand, and temporal separation is required. Similar joint operations have been successfully implemented in New Jersey and other locations where DMU or LRT service has been implemented with existing freight rail service.

5.6 Maintenance Requirements of DMU equipment

DMUs have typically required their own dedicated maintenance facility because the engines are different than traditional diesel locomotives. Engines are typically either truck or bus engines; and each DMU has at least one. A review of current DMUs in operations shows that nearly all have their own maintenance facility. The DART facility, which can maintain up to four DMUs at a time, cost $7.5 million to construct in 1996. The new SMART maintenance and operations facility is estimated to cost $12 million to construct and be approximately 52,200 sq ft in capacity. The new maintenance facility will perform all scheduled maintenance (propulsion, brakes, controls, heating, air condition etc.), FRA required inspections, repair record keeping, and service to the vehicles (fuel, lubricants, cleaning). It will also be a 24-hour, 7-day a week operation with maintenance technicians and servicing crews available around the clock, or as needed to meet service requirements. Most of the maintenance and servicing will be done at night when service is reduced or on weekends. A separate signal and maintenance-of-way facility will be built to maintain those systems. The signal and maintenance-of-way facility will be responsible for signal, track, and switch inspection maintenance, and repair, bridge maintenance, platform cleaning and facilities maintenance.

An exception to the above general maintenance practice among various agencies is GO Transit's Union Pearson Express. In that instance, the UP Express DMU equipment is serviced in the same facility as GO Transit's conventional rail equipment. Similar equipment and staff performs similar maintenance activities on both fleets.

The requirements for vehicle maintenance will vary with the size of the fleet. The amount spent on vehicle maintenance can range from as low as 3% to as high as 43% of the operating budget for compliant vehicles[80]. The cost per vehicle maintenance for all DMUs ranged from $19,900 to $249,000 per vehicle. The least expensive and most expensive were the Stadler GTWs. The compliant version operated by DCTA was the least and the non-compliant by NJ transit was the most.

5.7 Benefits and Challenges

There are multiple benefits of implementing service using DMU technology. DMU vehicles are smaller in size, have better fuel economy and are more environmentally friendly than their counterparts. These vehicles are also more efficient in terms of acceleration and deceleration capabilities, which allow for better travel times between closely spaced stations. In comparison to other vehicle technologies, DMUs typically have initial lower capital costs. DMU vehicles could dramatically improve rail service in Connecticut because they are more flexible and can be scaled to meet changing community needs, which allows for better matching between demand and capacity. In the event one engine fails, service would not be halted as the DMU vehicles can be equipped with a second backup engine or the vehicle can be pulled by another DMU unit.

One of the main challenges in using DMU vehicles along the CCRS corridor is operating on shared tracks with the existing freight service. DMU vehicles are required to meet stringent safety standards if they are operating on shared tracks to be compliant with FRA regulations. Not all manufactured DMU vehicles are classified as FRA-compliant, but the new Nippon Sharyo DMUs offer the first in service example of FRA-compliant DMUs in shared tracks. If vehicles are non-compliant, they may only share tracks with FRA-compliant vehicles if they receive a waiver from the FRA by demonstrating other satisfactory safety measures. Temporal separation can be used for non-compliant DMU vehicles, however, this can limit the hours of operation for passenger rail service. Under temporal separation, each service is essentially given a window of time when they may operate to ensure there is no overlap between the two. The existing freight service only runs a handful of times each day. Depending on how the temporal separation is implemented, DMU service may be able to operate during peak times without interfering with freight service.

In the procurement of DMU vehicles, another challenge can be abiding the Buy America legislation, which only allows federal funding for orders where at least 60% of the final product is built in the U.S. This can pose a slight speedbump in the procurement process as many DMU manufacturers are located outside of the U.S. In the past, this has not deterred other agencies from purchasing vehicles from foreign companies. Should DMU vehicles be chosen for the CCRS corridor, the state can still satisfy the Buy America requirement in order to receive federal funding. One way to meet the requirement is for the manufacturer to build the parts overseas, and then ship them to the U.S. for final assembly.

[80] A review of NTD data was conducted on all systems designated as “YR” hybrid rail. Hybrid rail is defined as “Rail systems primarily operating routes on the National system of railroads, but not operating with the characteristics of commuter rail. This service typically operates light rail-type vehicles as diesel multiple-unit trains (DMU’s). These trains do not meet Federal Railroad Administration standards, and so must operate with temporal separation from freight rail traffic”

Chapter 6. Conclusion

In general, DMU's are becoming more reliable and bring serviceability and maintainability. The DMU technology has a proven history that has only been enhanced environmentally, now achieving Tier 4 compliance and the option of customer WiFi onboard. Costs for operations continue to be higher than most conventional rail as modern DMU equipment is still relatively new in the industry, typically provided by foreign manufacturers, and there are long lead times for spare parts.

The following general list of Lessons Learned can be a guide to assist with the implementation of DMU service to help avoid problems that other agencies have addressed made when making similar implementations. Further Lesson Learned information is detailed below.

The lessons learned from the case study reviews can be divided into four categories: Operational, Infrastructure/equipment, Political, and Funding/Costs.

Table 10. Lessons Learned from DMU Implementation Nationally

Operational	
1.	Temporal separation limits service hours. If possible, utilize fully compliant DMU's with buff strength and other requirements allowing joint passenger / freight service without time separation.
2.	If freight rail breaks down overnight and cannot be fixed and moved by the morning, the DMUs would not be allowed to operate and service would be halted. Recovery procedures have been implemented to accommodate this concern.
3.	Similar to any mechanical fleet, thorough and regular maintenance inspections can prevent unnecessary service interruptions.
4.	DMUs are flexible operationally and can operate independently or as part of a group depending uponexisting service requirements.
Infrastructure/equipment	
1.	Single track with passing sidings requires headways that may not be as frequent as desired. Additional double track sections can be added later as the Service Plan changes to meet demand.
2.	Station modifications may be needed if operating different vehicle types in order to accommodate level boarding. Other agencies have successfully implemented strategies (gauntlet track, etc) to address this issue.
3.	Using European equipment takes a long time to procure replacement parts. Several US manufacturer's are in process of getting FRA approvals.
4.	Limit the number of at grade crossings; utilize standard safety measures (SSM) such as improved flashers and gates, medians, etc and Alternative Safety Measures (ASM) as defined by FRA to improve safety; utilize a diagnostic team approach for each crossing treatment design with all required stakeholders (FRA, CTDOT, local municipalities represented.
5.	Track Circuit Shunting can be an issue; utilize new technology signal and train control

	equipment to improve train detection as other agencies have done. Require the selected DMU manufacturer to address this issue in DMU design to maximize safety.
6.	Purchasing a one-off model can create repair and maintenance complications and could temporarily halt service; utilize a similar DMU design proven in service on another system, with minor changes; this will allow economies of scale for production.
7.	Larger manufacturers typically would not accommodate small orders and piggybacking with another Agencie's contract may significantly decrease the cost per unit and expected delivery time. FTA has been supportive of joint fleet procurements.
8.	Make sure each unit has two diesel engines and can be hauled by a second DMU in an emergency with little if any service impacts.
9.	Single track and a lack of passing sidings has resulted in increased rail traffic congestion. Initial Track and signal improvements should accommodate future service expansion without major rework.
10.	It can be difficult to procure replacement parts for routine maintenance in a timely manner since the vehicles are foreign made.
11.	DMUs are quieter and reduce the need for sound walls, and other vibration and sound deadening mitigation.
12.	Single track and a lack of passing sidings have resulted in less than desirable headways.
Political	
1.	Projects like these need a political champion to get approved.
2.	Need political support to back funding.
3.	If seeking an FRA waiver, meet with the FRA and start the process before the vehicles are procured in order to gain support.
4.	If the transit system is not seen in a positive light by the community, new projects will never get off the ground.
5.	Must have a good working relationship with the freight provider.
6.	Strong political support aided in procuring DMU vehicles for the service.
7.	Strong support from the local community is required; public outreach should start early in project planning.
Funding/Costs	
1.	DMUs are a more cost-efficient option.
2.	A local sales tax, such as Measure Q, can help fund the project. Innovative finance options are available and should be considered.
3.	Actively pursue all local, state and federal grant opportunities, including partnering with adjacent agencies for similar DMU procurement.
4.	If all the federal process criteria cannot be met then federal funding cannot be received.
5.	Local support to approve a tax increase to support the project is a must.
6.	Phasing of the project makes it easier to fund and build.
7.	Entering into agreements with others can reduce overhead costs.